SECONDARY SCHOOL SCIENCE

J. H. PHEASANT
M A., B SC , F L S
Institute of Education, University of London

AND

S. J. PARKIN
M.A , B SC , A INST P.
Lecturer in the Department of Applied Physics at the Northampton College o Advanced Technology, formerly Lecturer in charge of Science, Cordwainers Technical College

The Fourth of a Series of Four Books

BOOK ONE
How we Learn about the World around us

BOOK TWO
The Science of Our Surroundings

BOOK THREE
Ourselves and Science

SECONDARY SCHOOL SCIENCE

BOOK FOUR

The Science of Life and Pleasure

J. H. PHEASANT

S. J. PARKIN

ILLUSTRATED BY

IAN T. MORISON

D A.

LONDON: GEORGE ALLEN & UNWIN LTD

First published in 1958

Printed in Great Britain
in 12 point Imprint type
by Unwin Brothers Limited
Woking and London

PREFACE

THE three earlier books in this series together represent a planned concentric course in Science to cover the work of the first three years of the Secondary School course. In planning the present volume, the fact has been kept in mind that, while some pupils will complete the school year, many will leave at the end of the term in which they attain the age of fifteen. This book is therefore arranged not in chapters but in six sections, each complete in itself. Thus one or two sections may be covered in a term and pupils can complete a whole section or sections of the work before leaving school, whether this be after one, two or three terms.

The interests of girls, of boys, and of mixed classes have been catered for and Teachers will select those sections of the book which are most suitable for the needs of each class. It is expected that pupils will be able to use this book as a guide for individual work, referring to the teacher only when they need to do so. The lists of reference books and suggestions for activities by the pupils should enable them to work at their own pace and to enjoy following a line of independent study.

The book will be useful for girls and boys taking a more specialized science course in the last year, as for example, Pre-nursing, Human Biology, Domestic Subjects or Engineering. Furthermore, two of the sections will be of special interest to members of natural history and photographic societies.

Whereas the earlier volumes in this series were planned mainly for the Secondary Modern School, the present book, for the reasons given, will be of use in all types of Secondary School, both in the laboratory and in the library. The series as a whole will assist students in the Preliminary Training Schools of hospitals and in Training Colleges for Teachers.

BOOK 1 gives a preliminary view of the nature of matter, and of the senses through which we apprehend it, of some of the instruments which extend the range of our senses and of the scientific principles underlying them. There is a chapter on practical work in the Science Room It ends with an important biological project on the Oak Tree and the life associated with it, animals, birds, insects, fungi. There are also practical appendices on bird study, on how to keep and study insects, etc.

BOOK 2, *The Science of Our Surroundings*, deals at a more advanced level with the nature of the world in which we live and particularly with the science of the home, i.e. environment in relation to Man. There is work on the universe, the earth, minerals, living things past and present, weather, the structure of the house, energy in the home, and water. The project is on a Pond

BOOK 3, *Ourselves and Science*, is concerned with the structure of matter and with Man in relation to his environment. About half of the book is given over to human physiology and to the nature and treatment of food. Other chapters deal with the science behind bodily comfort, aids to seeing; men, work and machines; electricity. The book ends with a project on the Garden

CONTENTS

COMPARATIVE TABLE OF CONTENTS

Topic	Book 1 Chapter	Book 2 Chapter	Book 3 Chapter	Book 4 Section
Acids and alkalis	3		4, 11	1, 6
Air	1	2, 5, 7, 9	2, 3, 6, 7, 11	1
Astronomy		1		
Bacteria	3	8	2, 3, 4, 11	1
Carbon and its compounds	1	2, 3	5, 6	
Clothing and fabrics			7	6
Coal and other fuels		3, 7	6	4
Density		8		
Electricity		7	10	4
Energy		7	6	4
Evolution and Heredity		4		2
Field work	8	9	11	3
Forces			9	4
Gardening			11	
Geology—fossils		2, 4		
Heat	2	5, 7, 8	3, 7, 11	
House		6, 7		
Human body	1, 2, 3, 4, 5	4, 8	2, 3, 4, 5, 6, 7	
Indoor homes for animals	7	9		3
Light	5, 6	1, 7	8	5
Living things	1, 8	4, 9	6, 11	1, 2, 3, 6
Machines			9	4
Magnetism		3	10	
Matter	1, 3		1	
Measuring instruments	7	6, Appendix		
Metals		3, 6		
Pressure		5, 8	3	
Pressure, osmotic			5, 11	
Soap and other detergents		8	2	1, 6
Sound	4			
Water	7	2, 5, 6, 8, 9	4, 5, 7, 11	1, 3, 4, 5, 6
Weather		5		3, 6
Wood and timber	8	6		

SECTION 1

Bacteria and Public Health

IN BOOK I you learned that bacteria are microscopic living things which multiply very fast in favourable conditions. You learned that some bacteria are harmless to man (although they may be a nuisance), for example the red colonies you grew on decorators' size. Some cause food to decay, while others are responsible for many diseases. In Book II you learned how our water supply has to be treated in order to kill disease bacteria. In Book III you learned about the body's defences against bacteria and also about the work of the soil bacteria. In this book we shall deal more fully with bacteria in relation to everyday life.

Bacteria and the rotation of crops, nitrogen fixing bacteria

The lumps you will find on the roots of lupin, clover and other plants of the bean family (*Leguminosae*) contain colonies of bacteria which take nitrogen from the air in the soil, join it on to substances in the plant root and make protein. Thus plants in this family contain protein they have made from nitrates they absorb from the soil (Book III), plus an extra amount made from "free" nitrogen of the air. You will remember that peas, beans and lentils are good protein foods.

For hundreds of years, farmers have practised rotation of crops in which clover or vetch is grown every three or four years and ploughed into the soil. The extra protein made by the nitrogen fixing bacteria, as well as the protein

made by the green plant itself, is then changed by decay bacteria into ammonium salts which are oxidized to nitrates by the nitrifying bacteria in the soil (Book III). British plants belonging to the *Leguminosae* family can be recognized because they have flowers shaped rather like those of the sweet pea. Look at a head of clover with a hand lens. How many flowers can you count?

Other useful bacteria

Linen threads are made with the help of bacteria which rot the softer parts of the plant, leaving the tougher, bast fibres (Book III). Other bacteria are responsible for the flavour of different types of cheese and of tobacco. Some convert milk into Yoghurt and some are used in the preparation of leather from animal hides. Others are used in the preparation of silage (a valuable cattle food made from grass): still others help to give the pink colour to ham. Try to discover other processes in which bacteria play a useful part.

Bacteria as living things

Bacteria are found almost everywhere. Most of the characteristics of living things are true for them (Book I, p. 21), but some bacteria do not use oxygen, and we can often check the reproduction of such bacteria by exposing them to oxygen of the air or to oxygen set free from chemicals. Hydrogen peroxide is one such chemical. Although they are placed in the plant kingdom, bacteria do not contain chlorophyll and so cannot make their own food. Some obtain food from other living creatures, for example from the human body. These are *parasites*. Others, called *saprophytes*, get their food from decaying or other non-living material.

Each bacterium is a single living cell. Given a suitable temperature, food and water bacteria reproduce by splitting into two. If one bacterium splits into two in twenty minutes, in one hour it will have produced eight,

Louis Pasteur (1822–95) working in his laboratory
(*Wellcome Historical Medical Museum*)

in two hours sixty-four, and so on. Can you work out how many there would be after twenty-four hours? (In fact, they do not multiply quite as quickly as this, because bacteria, like other living things, produce waste substances which tend to destroy the bacteria in time.) Large colonies of bacteria, each formed from one cell, can be seen with the naked eye. You will find from the experiments on p. 39 that colonies of different kinds of bacteria may be of different colours. Like other living things, bacteria are killed by great heat, boiling water or steam, and poisons.

If bacteria have no suitable food or no water they cannot multiply. Many produce thick-walled spores which lie dormant for a time. These are much harder to destroy than are the active forms.

PRESERVATION OF FOOD

Some bacteria and moulds such as those seen on stale bread (Book II), cheese or jam, cause food to decay. Bacteria and tiny mould spores fall from the air on to everything around us. On food they may multiply and cause decay. Here are some ways of preventing this:—

1. Kill bacteria and mould spores which have already fallen on the food, then seal the food in containers so that no more bacteria and spores can reach it.

In *canning*, food is cooked in a vacuum and steam is used to kill all bacteria.

In *bottling*, the heat used to cook the food also destroys bacteria and drives all air from the jars. If the heated lids are screwed or clamped on to the jars immediately afterwards, the jars should be airtight since the lids will be kept in place by the pressure of the air outside the jar. Make a list of foods which are canned or bottled.

Acid fruits, for example plums and apples, can be preserved in water to which Camden tablets have been added. The acid in the fruit sets free a gas, sulphur dioxide, which kills many decay bacteria. The jars are then carefully sealed. Small quantities of sulphur dioxide are dissolved in some bottled fruit juices. On p. 41 you will find directions for preparing the gas and for carrying out experiments with it.

2. *Pasteurization of milk* kills certain disease bacteria without destroying the food value of the milk. Nowadays this is done by keeping the milk at a temperature of 161°F.

for fifteen seconds. Disease bacteria which may have got into the milk from the cow, milker, or milking equipment are destroyed.

3. Prevent bacteria and mould spores from obtaining water.

(*a*) By boiling fruit with sugar we preserve it as jam. The large quantity of sugar in the jam acts in the same way as the sugar solution in the osmosis experiment in Book III, p. 170, and bacteria falling on the jam will not have enough water to allow them to grow.

(*b*) By drying and smoking fish and salting meat.

4. *Refrigeration* prevents bacteria from multiplying and so food in a refrigerator keeps fresh longer. It is important to remember however that bacteria are not killed by refrigeration and that they will multiply quickly when the food is brought into a warm room or when the refrigerator is defrosted. Perishable food should be kept in the refrigerator until just before it is to be used.

OTHER METHODS OF DESTROYING BACTERIA

It is important to remember that fresh air, sunshine, and soap and water are excellent weapons which normally healthy people can use to protect themselves against disease. When necessary, utensils and linen used by a sick person should be disinfected. A disinfectant is a chemical which will poison certain bacteria. Often we need to use on the body a chemical which will not harm the delicate living cells but will make a wound, for example, unfit for disease bacteria to multiply. Such a chemical is called an antiseptic, since it is used not to kill bacteria which are already there, but to prevent their multiplication. Some antiseptics are weaker solutions of disinfectants, but

some, for example boracic acid, are so mild that they can never kill bacteria. When all bacteria on an object have been killed we say that it has been sterilized. Sterilization may be carried out by disinfectants or by dry heat, by boiling, or by steam from water boiling under more than atmospheric pressure. You will remember that such water will have a higher temperature than ordinary boiling water (Book III, p. 42). The last method is useful for killing spores of bacteria as well as the active forms. All surgical dressings and instruments used by surgeons, doctors and nurses must be sterilized before use.

Ultra-violet light is a powerful germ-killer (germicide).

SOME CHEMICALS USED TO STERILIZE NON-LIVING OBJECTS

1. *Chlorine* is used to sterilize our water supply. It is often used to kill bacteria in the water of swimming baths. We sometimes use bleaching powder (a chlorine compound) from which chlorine is set free when acid is added) to kill bacteria in toilets and drains. We can disinfect sheets, washing-up towels and handkerchiefs with solutions of "chlorine bleach." When you have carried out the experiments on p. 41 you will be able to say why this treatment is unsuitable for some coloured materials.

2. *Sulphur dioxide*.

3. *Formalin* is a liquid germicide which can be sprayed to disinfect a room after a patient has had an infectious disease. (It is also used to preserve zoological specimens.)

4. *Carbolic acid*. Lord Lister insisted that all doctors and nurses present at an operation or at the birth of a baby should disinfect everything they used with carbolic acid. He saved the lives of many people who would other-

wise have died from infected wounds. Carbolic acid is still used as a disinfectant but nowadays a number of other substances such as Dettol and Roccal are more widely used.

BACTERIA AND DISEASE

Pathogenic bacteria (those which cause disease) in the air have all come from sick people or sick animals. They are parasites and most of them cannot live long outside the body. People who can spread a disease are:—

1. *Those suffering from the disease.* We may obtain medical treatment for them; perhaps isolate them and kill bacteria by disinfecting things they use.

2. *Those incubating the disease.* These people are infectious because the germs are multiplying inside the body but there are not yet enough to produce symptoms of the disease. For example, the incubation period for measles is seven to fourteen days and the child is infectious from the fifth day. If we know that a child has been in contact with an infectious disease we can keep him away from other children until the incubation period is over.

3. *Those who are carriers of a disease.* Some diseases, for example typhoid fever and diphtheria, can be carried from one person to another by people who are not ill but harbour germs which they can pass on to other people. Such people are "carriers" of the disease and are a danger to the community. People known to be carriers are tested periodically by the hospital. They may not handle food which others will eat. If they move to another district the Medical Officer of Health must be informed. The best-known example of a carrier (of typhoid fever) was Mary Mallon, now known as "Typhoid Mary." She had suffered

from the disease but was apparently cured. In the next few years she worked as a cook in several areas and her arrival in each place was followed by an outbreak of typhoid. Eventually she was given different employment under strict hospital supervision, and she remained in hospital for the rest of her life. Nowadays the drug chloromycetin is sometimes successful in killing the bacteria which make a carrier infectious.

COMBATING BACTERIA INSIDE THE BODY

1. *The Sulphonamide drugs*

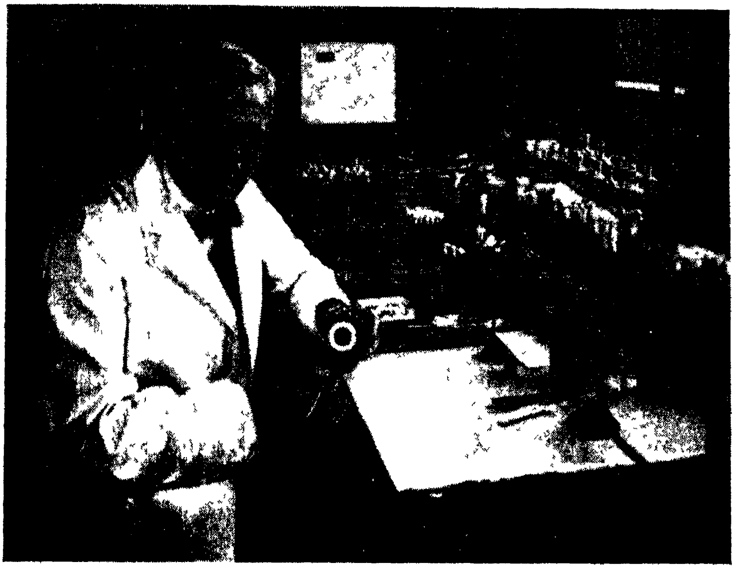
In 1936 a drug belonging to a group known as the Sulphonamides was successfully used to combat certain bacteria inside the human body without killing the patient. Other drugs in this group were then found to stop the multiplication of disease bacteria which had previously caused many deaths. The Sulphonamide drugs do not kill the bacteria but they stop their growth and then the normal defences of the sick person can often destroy these bacteria (Book III).

The use of these drugs for fighting diseases is of the greatest importance.

The value of Sulphonamide drugs for fighting disease is one of the most important discoveries of the first half of this century. They can be swallowed. They travel in the blood stream to all parts of the body, acting on certain kinds of bacteria, wherever they may be. The body does not destroy these drugs. They are excreted in the urine and so can be used for treating diseases of the kidney system. They have already saved countless lives and few people nowadays go through life without being treated at some time with one or other of them.

2. *The Antibiotics*

Drugs belonging to another group, discovered during the first half of the century, actually kill bacteria in the body. This is an advantage because these drugs can be used to cure very sick people whose defences have become



Sir Alexander Fleming in his laboratory

(*Keystone*)

too weak to fight bacteria at all. The first of these, Penicillin, was extracted from a mould related to the green one which grows on stale bread. At St. Mary's Hospital, Paddington, in 1928, Sir Alexander Fleming discovered that a mould growing on a culture of bacteria produced a substance which travelled through the culture and killed the bacteria in a remarkably powerful way. The substance

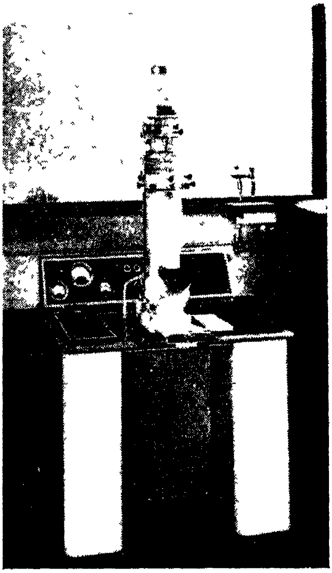
was found to be harmless to the human body. During the Second World War, Florey and a team of chemists at Oxford set to work to concentrate the drug which Fleming had named Penicillin after the mould, *Penicillium*. Florey's team went to America where the drug was manufactured on a large scale and it was first used to treat war wounds. Nowadays, it is widely used by surgeons and doctors for treating a number of infections and it has already saved innumerable lives.

Since the discovery of Penicillin many other germ-killing substances have been extracted from fungi. Some of them are poisonous and cannot be used as drugs. Others have been found useful for treating some diseases which do not respond to Penicillin. Research workers continue to look for new disease-destroying substances and we can confidently hope that certain diseases which are fatal today may be conquered in the near future.

VIRUS DISEASES

Have you ever noticed that some plants of wallflower and stock have striped flowers? The gardener calls these streaks "colour breaks." This marking shows that the plants are suffering from a virus disease. Leaves of other plants attacked by virus diseases may show other signs such as yellowing, mottling, and peculiar forms of growth. Measles, chicken-pox and the common cold are virus diseases of human beings. Foot and mouth disease is a dreaded disease of cattle, sheep and pigs. The particles of a virus are much smaller than bacteria. They were first seen under an electron microscope about twenty years ago. In some ways they behave as living creatures do. Inside the body or in a plant a virus will multiply. Viruses are destroyed by heat, but on the other hand they form

crystals as many laboratory chemicals do. Besides infecting animals and plants, viruses may infect bacteria. Virus diseases in man and animals are spread in the same ways as bacterial diseases. In plants they are frequently carried from diseased to healthy plants by insects such as aphids which suck sap from soft green stems and leaves. They travel through the sap of plants and so cuttings, bulbs, and tubers from an infected plant often contain the virus. Potato tubers (called "seed potatoes") are sent to Southern England each year from Scotland and Northern Ireland where the aphids which carry the virus cannot flourish in the damp atmosphere. The virus responsible for the mosaic disease of tobacco remains active in many cigarettes and tomato plants can be infected by this virus if a gardener smokes while he works among the growing plants. We do not yet understand why healthy plants may often grow from seed of infected plants of many kinds.



The Electron microscope
(*Metropolitan-Vickers Electrical Co.*)

PREVENTIVE MEDICINE

You will remember from Book III, pages 27 to 36, that the human body has its own natural defences against disease. The maintenance of good general health and

general cleanliness will assist these defences to keep the body healthy. As prevention is better than cure, research workers are constantly trying to discover new ways to help people to resist (become immune to) various diseases.

Immunity to disease

You may have wondered how doctors and nurses keep fit when they are in contact with so many sick people, or why you yourself did not contract measles when your brothers and sisters had it. Some people are naturally resistant to certain diseases. Some acquire this immunity after having had even a slight attack of the disease. The blood of such people contains substances called antibodies which fight the disease if it passes the natural defences of the body. These antibodies can be passed from a mother to her child during the nine months before the baby is born (see Book II) and so the baby is protected from certain diseases for the first few months of its life. We may be immune to some diseases throughout our whole life and to others for a shorter period. We may be given artificial immunity against certain diseases by inoculation or vaccination. In order to understand how this happens we must know something more about the way bacteria and viruses behave inside the body.

When disease bacteria or viruses get into the body they are surrounded by food and moisture. At body temperature they can multiply very rapidly. They produce waste substances and these collect in the tissues or blood stream of the patient. These waste liquids are called toxins and they produce the symptoms of the disease, for example fever, pain, vomiting, a rash, etc. The cells of the body produce antibodies which counteract the poisonous toxins and, if all goes well, the symptoms of

the disease disappear. Some antibodies will remain in the body and if, while they are present, bacteria or a virus responsible for the same disease pass the defences of the body the antibodies act quickly. Even if the disease is contracted, it is often in a very mild form. After the person is cured, dead bacteria are present in the body for a short time.

Vaccination

Bacteria can be grown in the laboratory (cultured) on nutrient material such as broth or jelly. Viruses can also be cultured but only on living material such as chick embryos. Louis Pasteur found that a culture of the virus causing chicken cholera weakened when kept for a time and when this was injected into healthy fowls, the birds became immune to an attack of cholera. The inactive virus caused antibodies to form and these remained in the fowls and could counteract a later attack by more powerful cholera virus. Ritchie Calder, in *Profile of Science*, calls the weakened form, "tame, domesticated viruses."

Culturing a virus in a chick embryo Viruses causing the common cold and influenza can be multiplied in this way, for purposes of research
(*Medical Research Council*)

A suspension of weakened virus or bacteria in a fluid for injection into

a person or animal is called a *vaccine*. For some diseases the bacteria are killed before injection. In 1881, Pasteur successfully vaccinated sheep and cattle with weakened anthrax bacteria. Then he vaccinated a child who had been bitten by a mad dog and who would otherwise certainly have died of hydrophobia. The child did not die but recovered. Pasteur's work helped to explain the discovery by Edward Jenner, in 1796, that liquid taken from a person suffering from cow-pox and injected into a healthy person would protect the latter if he came in contact with the much-feared small-pox. Nowadays, calves are injected with cow-pox virus. When they develop the disease, vaccines are prepared for use on human beings. Vaccination against small-pox is recommended for all babies, and again at seven, fourteen and twenty-one years of age. For people travelling to countries where there is danger of contracting the disease, vaccination is compulsory before leaving the United Kingdom. Many people believe that vaccination has undoubtedly stamped out small-pox in the United Kingdom, but the great advance in standards of personal hygiene and the work of the public health services may well have helped in this achievement. A vaccine to protect against tuberculosis, the Bacille–Calmette–Guérin, or B.C.G. vaccine, is now used on children who have been tested and found to be susceptible to this disease. The results are promising. Another vaccine is now being used to protect against another dread disease, poliomyelitis.

Inoculation

For diseases such as scarlet fever, whooping cough and diphtheria, the liquid containing dead bacteria and toxins is filtered to get rid of the dead bacteria, before it is

injected into a person. This injection of liquid only is called inoculation. Each year, many children are inoculated. The great value of inoculation has been seen in the remarkable drop in the death rate from diphtheria, following the campaign for inoculation of as many young children

Inoculation (*Picture Post*)

as possible. On the next page are some figures showing how the death rate is falling as a result of this inoculation.

From the beginning of 1940 until the end of June 1955, 11,685,523 children had been immunized. (From Ministry of Health Circular No. 4/56.)

Year	*Children who contracted diphtheria*	*Deaths*
1948	3,575	156
1949	1,890	84
1950	960	49
1951	664	33
1952	376	32
1953	266	23
1954	173	9
1955	161	10

HOW DISEASES REACH US

Bacteria and viruses responsible for disease can reach us in four ways:—

1. *By contact*, either by touching a sick person or by touching crockery, books, papers, toys, washing utensils, towels, etc., used by the sick person.

2. *In dust and droplets from the air.*

3. *In food and water.* Milk may be infected from a diseased cow, or from a milker suffering from any infectious disease, a septic finger, or sore throat. Dirty utensils can also infect milk, or it may become contaminated in the home from flies and dust.

Water, if contaminated with sewage, may cause typhoid fever and other diseases (Book II).

Disease bacteria from unwashed hands of kitchen staff can be deposited on food and cause food poisoning.

4. *By insects and other animals.* Certain insects and other animals may carry disease bacteria and viruses to food. They may also inject diseases into man, for example, the malaria-carrying mosquito.

SOME INSECTS WHICH CARRY DISEASE

1. *The Housefly*

This insect carries disease bacteria which may cause the death of young children. It also carries bacteria which produce food poisoning in adults.

The female fly lays a batch of about a hundred small white eggs in such places as rubbish heaps, manure heaps, dustbins, dirty crevices in kitchens, and other places where dirt and bacteria accumulate. In a suitable tempera-

The Housefly (*Mustograph*)

ture, the eggs hatch after about twelve hours to white legless grubs (larvae), which feed on liquid produced by the decaying refuse. Soon the grubs burrow into the rubbish and turn into pupae which are white and rounded at both ends. Inside the pupae, metamorphosis occurs and in a few days a fly emerges from each pupa and crawls up through the refuse before flying off to find other food.

When the adult fly reaches uncovered food such as sugar or milk it projects a curious tube-like "tongue" (proboscis). Digestive juice, containing bacteria, is forced through this tube on to the food. Some of the food is dissolved and is sucked up, with the juice, into the fly's body. Bacteria may be left on the food in this way and also from its hairy legs as the fly crawls over the food. Some bacteria pass through the fly's digestive system and may be deposited on uncovered food.

We can prevent the contamination of food by flies by:

(*a*) keeping all food covered,

(*b*) keeping dustbins covered and away from the house in a place where they can be emptied frequently,

(*c*) cleaning all crevices in the house where flies may breed,

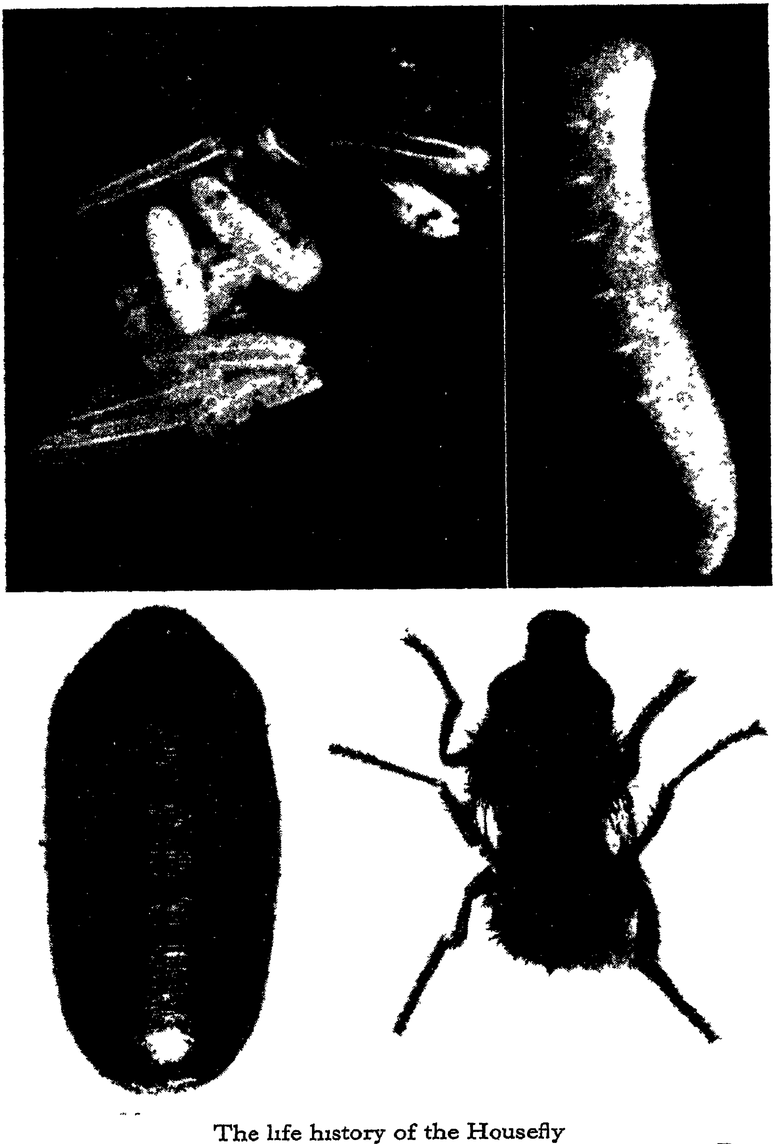
(*d*) killing flies and larvae with an insecticide spray,

(*e*) burning rubbish or sprinkling borax on rubbish heaps, and

(*f*) turning over manure heaps frequently.

(Revise the structure and life cycle of an insect: Book I, pp. 114–15 and 124–7.)

(Revise work of digestive juices: Book III, pp. 50–58.)



The life history of the Housefly

1. Eggs   2 Larva   3 Pupa

4. Fly crawling out of refuse The wings are expanded later, in the air

(*Mustograph*)

A Housefly walked over a sterilized jelly plate. Colonies of bacteria and moulds have developed on the jelly wherever its feet and proboscis rested. (*Picture Post*)

2. *The Mosquito*

While mosquitoes in this country merely give us a painful bite, in many other parts of the world some of them carry deadly diseases. Malaria, which was once thought to be caused by breathing the damp air of swampy places, killed millions of people every year until it was discovered that the disease was carried from one person to another by mosquitoes.

The disease is caused not by bacteria or by a virus but by a microscopic animal, the malarial parasite. This tiny creature spends part of its life in the body of a certain type of female mosquito and part in the blood stream of men, monkeys, antelopes and some other mammals. When one of these female mosquitoes bites a person or one of

these other mammals, it sucks up blood which may contain the parasite. Inside the mosquito, the parasite lives and multiplies. When the mosquito bites another person, some of the parasites are injected into his blood and an attack of malarial fever soon follows. Every year, millions of people in the under-developed areas of India, Africa and the Far East die from malaria. The disease is particularly fatal among young children. Until the discovery of the use of quinine in the treatment of malarial fever, travel in tropical countries was very dangerous and the development of these areas was therefore long delayed. The patient and painstaking research by which Sir Ronald Ross established the true cause of malaria is one of the great feats of science.

In countries where malaria is prevalent people are urged to avoid being bitten by mosquitoes (by wearing protective clothing and using mosquito nets over their beds) and to take quinine and other drugs as preventive medicine. The most successful methods of stamping out malaria, however, have been (*a*) draining swamps where mosquitos breed, (*b*) spraying all standing water with oil to kill the mosquito larvae (Book II, p. 166), (*c*) spraying walls and furnishings of houses with DDT or Gammexane to kill the adult mosquitoes.

Another type of mosquito carries the organism which causes yellow fever, a tropical disease for which, until recently, no cure was known. The first attempts to construct the Panama Canal failed because so many of the workers died of this disease. Then Colonel Gorgas and the American Medical Service drained the swamps and so destroyed the breeding places of the mosquitoes. Then the great shipway was successfully completed.

With the development of air travel special measures have to be taken to prevent the spread of these diseases.

Aeroplanes travelling through countries where mosquitoes breed are sprayed with an insecticide at the beginning and end of every flight. People travelling through or to tropical areas are required to be inoculated against yellow fever and are supplied with a preventive medicine against malaria.

3. *Fleas*

Bubonic plague is a fatal disease caused by an organism injected into the human body by the bite of an infected flea. Some fleas are parasites, living in the fur of the brown rat which is found throughout the world. The Black Death was an epidemic of bubonic plague which reduced the population of Europe by millions during the Middle Ages. Each outbreak of the plague among rats was followed by an outbreak among the inhabitants of the area. For infected fleas left the bodies of dead rats and sucked blood, which is their food, from human beings, who thus became victims of the disease. Bubonic plague is still prevalent in many countries where governments do not take energetic measures to destroy rats. Its return to this country is prevented by strict measures on board ships and at the ports and by the activities of the Public Health authorities. (Rats are also responsible for an infection of duck eggs. Eggs of water ducks may contain *Salmonella* bacteria which get into water from the urine of rats and then pass into the oviduct of the bird and infect the eggs she lays. These bacteria are killed if the eggs are boiled for at least ten minutes. So eggs of water ducks may be used in cake making or hard boiled but should not be scrambled, soft boiled or used to make dried egg or synthetic cream.

Besides carrying disease, rats cause immense loss in all

countries by eating and spoiling vast amounts of food in granaries and warehouses.)

SOME INSECT PARASITES OF THE HUMAN BODY

Where people are not careful to keep themselves and their homes clean, or where there is serious overcrowding, insects such as fleas, body lice, head lice and bugs are commonly found living as parasites on the surface of the body. These insects feed on human blood and can cause great discomfort by their bites. Where skin has been broken by the bites, disease bacteria can enter. Wherever people are gathered together in large numbers there is danger that head lice may pass to even the cleanest people. The parasites can be destroyed by washing the hair with a special soap sold by all chemists. It is wise never to use brushes, combs, hats or caps belonging to other people.

Parasitic worms live inside the human body. Small thread worms, for example, are not uncommonly found for short periods in the intestines of young children. The tape-worm which used to be a common intestinal parasite has now, fortunately, become much less common owing to the careful inspection of all meat at slaughter houses and ports. No meat may be sold which has not been inspected. Even so, it is wise to cook all meat thoroughly. Sausage meat should never be eaten raw. People who have these parasites in their bodies are said to be the hosts of the parasites. Discomfort, anaemia and malnutrition are some of the results which may follow. Medical treatment can fortunately rid the patient of such parasites.

REFUSE DISPOSAL

It may seem surprising that in former times household rubbish was thrown on the streets and left there to decay.

In London and other large towns much of the refuse from houses and shops, including the contents of primitive toilets, was tipped into the river and its tributaries. The Thames became an evil-smelling, germ-laden waterway as it flowed through London. It was also the only supply of drinking water for many of the poorer people. Consequently disease and early death were prevalent. It has

London before the fire of 1666
(Notice how the houses are crowded together on the banks of the River Thames.)

been suggested that the expectation of life in the reign of Elizabeth I was about twenty-five years. The death rate among children was especially high.

Nowadays, those of us who live in towns are accustomed to well-kept streets and regular collection of household refuse. In many areas people keep waste food and waste paper in containers separate from the rest of the household

refuse. The waste food is treated to make it safe for feeding to animals (frequently to pigs). Paper can be sold for processing. The pulp is remade into paper.

In some areas all useful, saleable material is sorted from the general refuse and sold. Iron and steel are removed by a large electro-magnet. Other metals are also collected, as well as rags, cinders, bones and glass. The remainder of the refuse is burned. From 1939 to 1949 in Great Britain about 2,750,000 tons of paper, 2,000,000 tons of metal and 3,000,000 tons of kitchen refuse were sold for about £37,000,000. The sale of salvage helps to reduce the money paid as rates by householders for such services as education, a safe water supply, good methods of refuse and sewage disposal, and the cleanliness of roads among other things.

The older methods of tipping refuse on waste ground or into the sea far enough away from land to prevent its being washed back, are still used in some parts of the country.

SEWAGE DISPOSAL

Wherever people live and work, waste material from lavatories and water used for general cleaning must be removed from buildings and disposed of in a way which will not endanger the health of the community. *The water carriage system* is the modern method of sewage disposal in towns. Sewage from buildings travels along wide pipes or sewers to the disposal plant. There screens, consisting of vertical bars about $\frac{3}{8}$ in. apart, remove paper and some other solids. The sewage then flows through tanks where it is separated into solid sludge and liquid effluent. Bacteria are destroyed in both sludge and effluent. After this the effluent is pure enough to be safely passed into rivers. In some areas the sludge is used as a coarse soil

fertilizer after drying. In the newest method of drying by pressure and heat, the gas Methane (Marsh gas) is produced. This is collected and used for lighting and heating and to provide power for running machinery used in the process. (Methane is produced naturally under certain conditions in swampy places where plant material is decaying. Watch for "Will-o'-the-Wisp" over marshes on a warm evening. This curious flame is burning methane which has bubbled up from the mud and ignited in the warm air.)

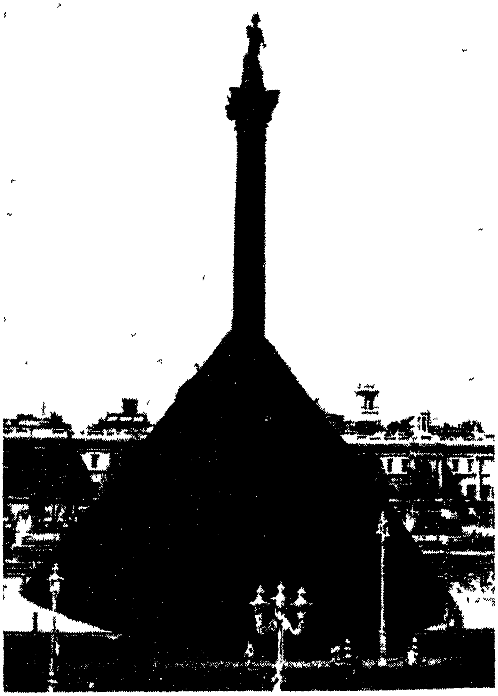
SMOG

Every day a great deal of smoke gets into the air around big cities. It comes from factory chimneys, from chimneys of houses burning coal on open fires, and from motor-vehicles. The smoke consists of soot (carbon) particles and gases, one of which is sulphur dioxide. In certain air conditions, for example, when a layer of damp air is trapped below a layer of colder air, and at certain air pressures, the water vapour in the trapped damp air condenses round the soot particles, forming fog. The sulphur dioxide produces an acid which may damage the lungs of people who have to be out in the fog. This is especially dangerous to old people and to those with chest or heart conditions. The soot in the air forms a black lining to the lungs of everyone living in industrial areas but the acid fog (smog) is a much greater danger. A mask of gauze or a scarf tied over the nose and mouth is recommended for use by everyone out of doors during a city fog.

The surfaces of buildings are blackened and damaged by the impurities in the air and a great deal of money must be spent each year in cleaning and repairing them. Clothing, too, becomes dirty much more quickly in towns

than in the country. Can you think of other ways in which the smoke of our towns is harmful?

The use of fuels such as coke and anthracite, which produce little smoke, would greatly reduce the impurities



This cone of soot round the column of Nelson's monument in Trafalgar Square, London, represents the amount of soot which falls on London from the air in a year. The column is almost 185 feet high.
(*National Smoke Abatement Society*)

in the air and remove an unnecessary cause of discomfort and even of death.

SOME QUESTIONS TO TEST YOUR KNOWLEDGE

1. From what sources do (*a*) parasites and (*b*) saprophytes obtain their food? How do (*a*) normal animals and (*b*) normal plants obtain their food?

2. Name the ways in which food may be preserved. Say how each method prevents bacteria from multiplying.

3. What do we mean by sterilization, disinfectant, antiseptic, germicide? Name some germicides.

4. How may diseases be spread? How may they be combated (*a*) outside the body, (*b*) inside the body?

5. What do you know about Sulphonamide drugs and Antibiotics?

6. What do we mean by immunity to disease, antibodies, toxins, symptoms of a disease, vaccination, inoculation?

7. Say what you know about (*a*) bacteria (*b*) virus diseases.

8. Describe the life history of the housefly. How can we prevent illnesses caused by flies?

9. What do you know about malaria and its control?

10. Write notes on refuse and sewage disposal in the area in which you live.

THINGS TO DO

1. Find out about the trouble caused by the red bacteria (*Bacillus prodigiosus*) in the Middle Ages, from *Microbes by the Million.*

2. Read more about the Electron Microscope and how it works, in *Mumps, Measles and Mosaics.*

3. Prepare a short talk to be given to your class on virus diseases of plants. The book mentioned in 2 above will help you.

4. Find out all you can about the common cold, measles, chicken-pox.

5. Prepare a poster, warning mothers of the danger of diphtheria and telling how their children may be protected.

6. Make drawings to show the life history of the aphid which is responsible for "cuckoo spit" on plants.

7. If you live in a country district, find out all you can about foot and mouth disease. What precautions are taken to prevent its spread? What happens to infected animals?

8. Make a small book on one of the following:—

(*a*) The story of the discovery, preparation and use of Penicillin.

(*b*) Useful bacteria and their work.

9. Prepare a short talk to give to your class on the life and work of one of these people. Include dates of birth and death, mention in whose reign they lived, any important events happening in England at that time, something about their early life, their work and how it has helped mankind.

(*a*) Leeuwenhoek, the Dutchman who saw bacteria with a home-made microscope.

(*b*) Edward Jenner, who first vaccinated against small-pox.

(*c*) Lord Lister, who made operations safer by using disinfectants.

(*d*) Louis Pasteur, the French chemist who has been called the "Microbe Man."

(*e*) Sir Ronald Ross, who researched on malaria.

(*f*) Madame Curie—the "Radium Woman."

EXPERIMENTS WITH BACTERIA

1. Plunge your arm into a heap of grass cuttings. Bacteria in the damp cuttings multiply and during their respiration produce considerable heat. Can you explain why hay which is badly stacked sometimes catches fire? (Read *Microbes by the Million*, chapter 4.)

2. To half a pint of fresh milk add one teaspoonful of Yoghurt.

Mix well. Taste the mixture. Cover with muslin and leave in a warm place for several hours. Taste the mixture again. You inoculated the milk (culture medium) with a culture of Yoghurt-forming bacteria. What do you think has happened?

3. Mix a little decorators' size to a paste with hot water. Pour it into a Petrie dish or saucer and leave it in the air for about half an hour. Cover the dish and keep it in a warm place, for example, under or over a radiator, for a few days. Red colonies of bacteria may develop.

4. Make from this recipe a food jelly on which some bacteria will grow. Soak overnight 20 grams of gelatine in 200 c.c. of water in which a potato has been boiled for half an hour. Heat over a wire gauze on a tripod stand, stirring all the time. Add about an eighth of an Oxo cube or a very little meat extract. Boil for about fifteen minutes. While hot, pour a little into each of several Petrie dishes or medicine bottles or boiling tubes which have been boiled in water to sterilize them. Lids should also be boiled, and cotton-wool plugs for tubes and bottles should be baked. Cover or plug immediately and leave the culture solution to set. Slope the bottles or tubes so that a jelly slope is obtained. *Keep the jelly covered* until you are ready to use it. Why is this necessary?

Note.—Boiling weakens the setting power of gelatine, but for these experiments the solution must be sterilized by boiling.

Different members of the class might now carry out experiments 5–12 and any others you can think out for yourselves, using this food jelly.

5 Leave one covered plate as a control. You should compare all your other plates with this one. While you leave it covered, no bacteria can fall on the jelly. Label it "Control experiment."

6. Remove the lid of one culture plate. Press the fingers of one hand on to the sterile jelly for one moment and cover at once. Label this plate "Unwashed fingers."

Repeat with another plate after washing your hands thoroughly with soap and water. Label this plate "Washed fingers."

Repeat with a third dish after "scrubbing up" your hands with water to which a disinfectant has been added (follow the directions

on the bottle to get the correct strength). How will you label this plate? Leave these plates and the control for a few days in a warm place in the science room. Which culture develops the largest number of colonies of bacteria or mould? Can you explain this result? To be sure that your results are not due to accident, experiments should be repeated as many times as possible.

7. Place a pinch of floor sweepings on to a jelly plate or slope. Cover at once and label. Repeat this experiment with another plate to which a few drops of Dettol, Boracic acid or Thymol have been added. Can you explain the difference in the plates after a few days?

8. Uncover a jelly plate in a refrigerator which is defrosting. After a few minutes remove the plate, cover and label it. Did the air in the refrigerator contain bacteria? You will be able to say after you have kept the plate warm (incubated it) for a few days.

9. Place a pinch of fresh garden soil on jelly in a plate or slope. Cover, label and incubate.

10. Repeat experiment 9 using a drop of pond water or water from an aquarium instead of soil.

11. Trap a housefly in a medicine bottle containing a jelly slope. After the fly has crawled over the jelly for a short time, hold the bottle upside down, remove the plug and shake out the fly. Replace the cotton wool plug and label the bottle. After a few days' incubation in a warm place, notice the trail of colonies of bacteria. These have developed from bacteria left on the jelly by the fly.

12. Sterilize a piece of platinum wire substitute by heating it in the Bunsen burner flame. Dip its looped end into one of your colonies of bacteria and make stripes with it on another sterile jelly plate. Cover at once and incubate the plate. Sketch how colonies of bacteria develop.

Note.—Leave all these jelly cultures in a warm place so that any bacteria present may multiply quickly and form colonies. When you have finished your experiments, wash your plates in hot water after soaking them in disinfectant. Do not cough or breathe on the jelly plates and then incubate bacteria from your breath. Why might this be dangerous?

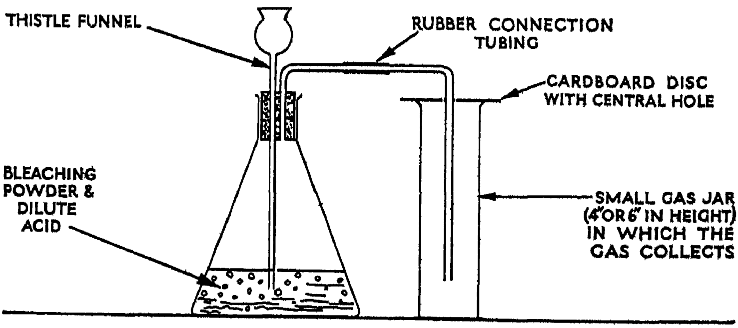
13. Pour fresh milk into two boiling tubes to a depth of one inch. Boil the milk and while still hot plug the tubes with baked cotton wool. When cold, remove the plugs and add to one tube a pinch of fresh garden soil. To the other add a pinch of soil which has been baked on a tin lid and cooled. Replace the plugs and label one tube "Fresh soil" and the other "Baked soil." After a day in a warm room remove the plugs for a moment and smell the milk in each tube. Re-plug and leave for another day. Do you notice any differences in the contents of the two tubes? Say what you conclude from this experiment.

MOULDS

If you have a microscope at school, try to see the moulds on bread, cheese, or jam very much enlarged. There is a drawing of the pin mould (Mucor) in Book II, p. 56. Some antibiotics were first prepared from moulds.

SOME EXPERIMENTS WITH CHLORINE

1. Prepare two small jars of chlorine gas using the apparatus in the sketch. The lower end of the thistle funnel must be below the level of the acid. Why is this important?



Apparatus for preparing chlorine gas.

Hold a white card behind the gas jar. When the green gas seems to fill the jar, remove the jar and cover with a vaselined glass plate. If the bubbling (effervescence) stops before you have two jars full, add a little more acid.

2. Replace the gas jar by a test tube containing two inches of caustic soda solution. This will absorb chlorine and prevent too much escaping into the air. Why is this important?

3. Collect small pieces of the following, moisten them with water and place them one after the other in a jar of chlorine:—(*a*) red and blue litmus papers, (*b*) ink-stained paper, (*c*) coloured wools, (*d*) newspaper with printer's ink, (*e*) paper with Indian ink, (*f*) coloured silk, cotton, (*g*) white silk, (*h*) white wool, (*i*) material with tea, coffee or blood stains. You might also use flowers and leaves.

4. Cautiously smell bleaching powder. You will remember that carbon dioxide and water make carbonic acid (Book II). The water vapour and carbon dioxide in the air gradually set free chlorine from bleaching powder.

5. Use the solution from experiment 2 or some household bleach to repeat experiment 3.

SOME EXPERIMENTS WITH SULPHUR DIOXIDE

1. With a Bunsen burner set fire to a little sulphur in a burning spoon and let the sulphur burn in a gas jar of air (Book I, p. 19). Remove the spoon and cover the jar with a vaselined glass plate. The burning sulphur joins with oxygen forming sulphur dioxide gas. Prepare two or three more jars of the gas. Make a diagram of the apparatus you used and label it to show how sulphur dioxide is formed.

2. Collect the following materials, moisten each with water and place in a jar of sulphur dioxide: (*a*) red rose petals, (*b*) green leaves, (*c*) printed paper, (*d*) coloured wools, (*e*) a piece of apple which has been left in the air until it is brown, (*f*) pieces of red and blue litmus paper. Make a list of your results.

3. Use the apparatus on p. 40 to make sulphur dioxide by another method. Put about a dessertspoonful of crystals of sodium sulphite in the flask and pour dilute hydrochloric acid down the funnel to cover the crystals. Make a diagram of the apparatus and label it to show what happens inside the flask. You might use these jars of gas to complete the tests in experiment 2.

4. Drop one crystal of permanganate of potash into a test tube half full of water. Pour the pink solution into a jar of sulphur dioxide. What do you notice?

5. Crush four Camden tablets (for preserving fruit) and dissolve them in one quarter of a pint of water. Pour the solution over fresh plums in a one pound jam jar and seal the jar with a moist cellophane cover. What do you notice after a few days?

6. Turn the plums and liquid into a saucepan. What can you smell? Why do you think plums, apples and rhubarb can be preserved with Camden tablets? Cook the plums in a saucepan without the lid. What happens to the appearance of the plums? What do you think has happened to the sulphur dioxide?

FILMS TO SEE IF POSSIBLE

Cuckoo Spit—The life history of the garden aphid. (Associated British Pathe.)

L'Oeuvre Scientifique de Pasteur—The story of Pasteur's life and work. There are copies with the sound track in English. (French Institute.)

Bacteria in Food (J. Lyons & Co.)

Sardinia Project—shows methods used to stamp out malaria in Sardinia. (Shell.)

The Pin Mould (Gaumont British.)

Cooking and Canning (Heinz 57 Varieties, Harlesden, Middlesex.)

The Right Food for Baby (Heinz.)

Taken for Granted (Sewage disposal.)

Guilty Chimneys (Air pollution.)

SOME EXPERIMENTS WITH HYDROGEN PEROXIDE

(You may obtain this chemical from any chemist.)

1. Drop a little hydrogen peroxide mixed with an equal volume of water on to a cut or scratch. What do you see and feel? Hydrogen peroxide will make a wound unfit for bacteria to multiply.

2. Think out and carry out an experiment to find the effect of hydrogen peroxide on litmus and other coloured or stained substances. Note your results.

SOME BOOKS YOU MAY FIND USEFUL

Nicol, *Microbes by the Million.*
Dorley, *The Microbe Man.*
De Kruif, *The Microbe Hunters.*
The Diary of Samuel Pepys (for details of the Plague and Fire of London)
Sherwood Taylor, *A Century of Science.*
Defoe, *Journal of the Plague Year.*
Sherwood Taylor, *An Illustrated History of Science.*

MORE DIFFICULT BOOKS YOU MAY LIKE TO CONSULT

Ritchie Calder, *Profile of Science.*
Nicol, *Microbes and Us.*
Smith and Markham, *Mumps, Measles and Mosaics*
Esdaile, *Harmful and Useful Animals.*
Gamlin, *Education and Health*
Drew, *Man, Microbe and Malady.*

SECTION 2

Heredity

HAVE YOU EVER WONDERED why you are like your Father in some ways and like your Mother in others? How does it happen that tall parents often have tall children? Think of some families you know where this is so. How does it happen that a father may pass on to his children brown eyes and curly hair while the mother, an excellent pianist, passes on her musical ability to their son? Perhaps you know of other families similar to this one. You may also have heard of families in which there is a tendency to have twin children. This passing on of characteristics such as height, eye colour, etc., from parents to their children is called inheritance or heredity.

Until the middle of the nineteenth century very little was known about the way such characteristics are passed on from parents to children. The first person to discover how things are inherited was an Austrian monk, Gregor Mendel (1822–1884). He experimented, not on people, but on peas growing in his monastery garden in the small town which is now Brno in Czechoslovakia.

MENDEL'S EXPERIMENTS

Like all good scientists, Mendel was very observant. He noticed that some peas were tall and others were short; some had coloured flowers and some had white flowers? some had wrinkled seeds, others had smooth seeds. He wondered how these characters (or factors) were passed

on from one generation to the next and he planned experiments to find out. Mendel was a careful and patient experimenter. All his experiments were repeated many times so that he might be as sure as he could be that his results were correct. He also kept very careful records of them.

Usually, peas are self-pollinated. The pollen from the stamens of a flower falls on to the stigma of that flower. Normally, flowers of the tall plants would be pollinated by their own pollen and would produce seed which would grow into tall plants. They would "breed true" to the factor "tallness." In the same way, dwarf plants would breed true to dwarfness. If this happens for several generations of plants, we say that the plants belong to a "pure strain" because however long they are self-pollinated, the new generations of plants will be roughly the same height as their ancestors. (Slight differences in height are called variations. They are not inherited.)

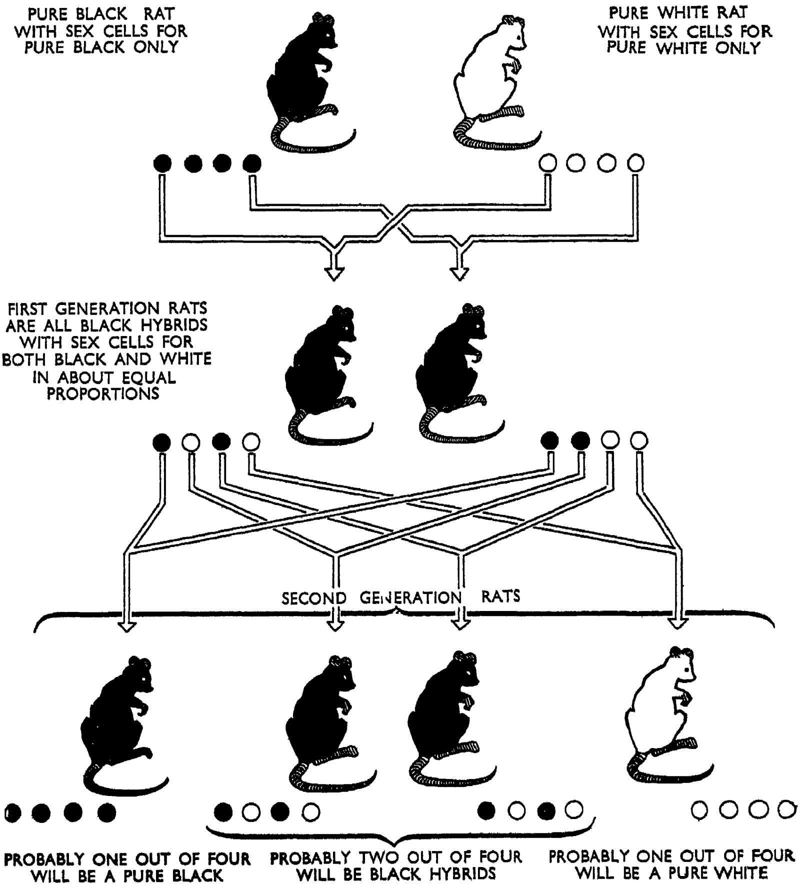
For his first experiments Mendel used pure strains of tall and dwarf peas. He decided to see what would happen if he took pollen from a tall plant and placed it on the stigma of a flower from a dwarf plant before that flower could become self-pollinated. He reversed the experiment, pollinating flowers of tall plants with pollen from dwarf plants. He repeated his experiments by crossing plants having coloured flowers with plants having white flowers, hairy plants with smooth plants, and so on until he had experimented with all the pairs of characters he had observed in his peas.

When the seeds were ripe he carefully collected them, keeping all the seeds from one flower together. He planted them and when the new plants grew, he compared them with the parent plants he had crossed to produce the seed. To his astonishment, the new generation of

plants seemed to have lost one of the two characters which he had tried to combine in the seed. For example, in his crossing of tall and dwarf plants, all the new plants were tall. Similarly, from the cross between white and coloured flowers, all the new plants had coloured flowers. The results were the same whether he had taken pollen from the tall or from the dwarf plants (or from white or coloured flowers). He called these new plants the first generation. He allowed them to be self-pollinated and again harvested the seed. When these seeds were planted and the second generation of plants grew, the character that had seemed to be lost, reappeared in some of the plants. There were about three times as many tall plants as dwarf ones, and of plants with coloured flowers as of plants with white flowers. This kind of result occurred no matter with which pair of characters he experimented. Again he allowed the plants to be self-pollinated, harvested the seed and planted it. In the third generation roughly one of every three seeds from tall plants bred true to tallness while the other two gave a mixture of tall and dwarf plants as in the second generation. The dwarf plants all bred true to dwarfness.

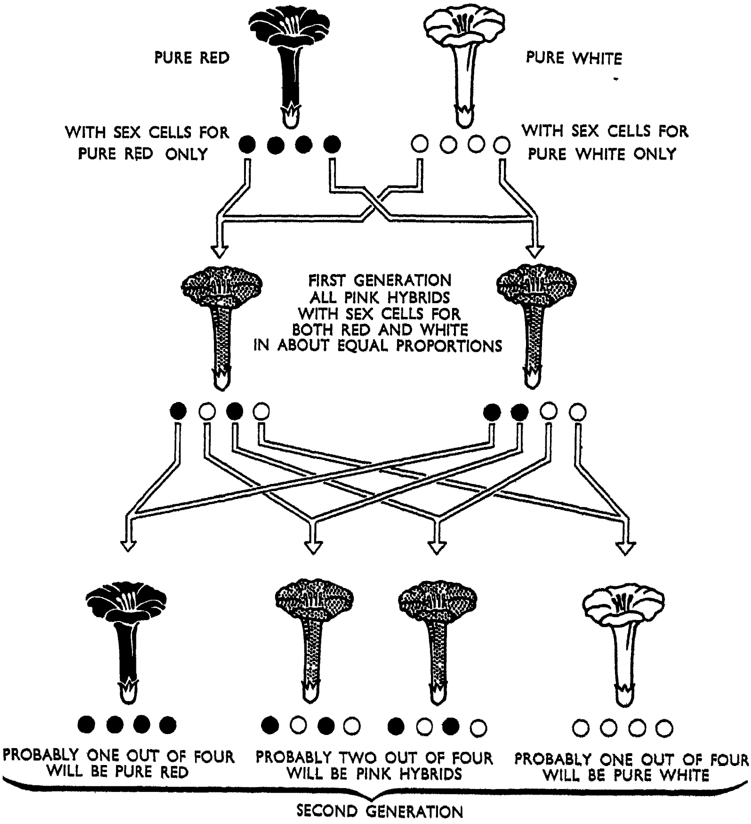
Mendel called the character which showed up in the first generation, for example, tallness, the dominant character. The character that was hidden, for example, dwarfness, he called the recessive character. He later repeated his experiments using different kinds of plants. He also carried out breeding experiments with animals. He concluded that the plants and animals with which he experimented possessed characters which were passed from parents to offspring in a definite way.

Mendel reported his discovery to the Natural History Society of his town. He died and for thirty years it was forgotten. Then at the beginning of this century, scientists



This drawing shows how the coat colour of rats may be inherited.

in England and America read his report and repeated his experiments. His work has become the foundation of the modern science of heredity (or genetics, as it is now



In a few kinds of animals and plants, one colour is not completely dominant to another This is so in the "five o'clock" flowers. The flowers of the first generation of hybrids are pink and not red. Follow the diagram carefully, and see how the colours separate out in the next generation.

The Blue Andalusian fowl is an example of incomplete dominance in animals.

called). This deals with problems of human heredity and with ways of improving cultivated plants and domestic animals.

How characters are passed on by the sex cells

Mendel knew that inherited characters are passed on by the sex cells and that both male and female sex cells are equally important. With our modern powerful microscopes we can see inside the sex cells, and scientists have discovered more about the way in which characters are inherited.

THE CHROMOSOMES

In every cell of the human body and of all living plants and animals there is a most important part, the nucleus. We now know that the nucleus, although it is very small indeed, contains a number of minute pieces of protoplasm called chromosomes. Each chromosome, when seen under the microscope, looks rather like a short string of beads.

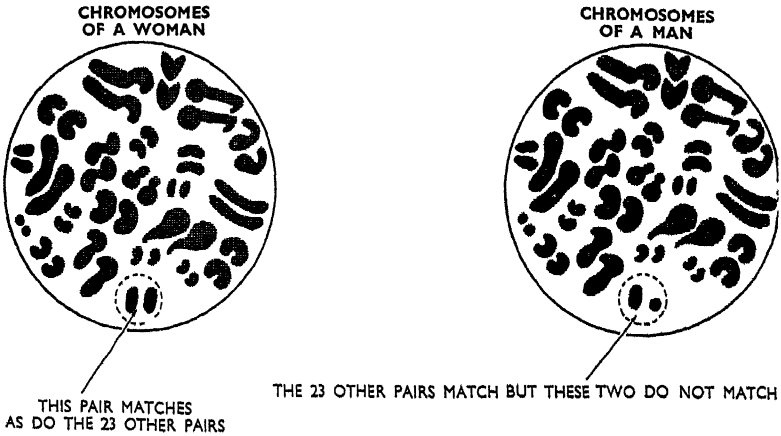
One chromosome in its "necklace" form

Every kind of plant and animal has a definite number of chromosomes in each of its cells. The number for human beings and also for the white lily is 48. The chromosomes differ from each other in size and shape; but, in every cell of the body except the sex cells, there are 24 pairs. In each of the sex cells there are 24 single chromosomes. We

believe that the inherited characters which are often called genes, are housed in the "beads" of the chromosomes, probably a number of characters to each "bead."

The sex chromosomes

Here are diagrams to show the 24 pairs of chromosomes in every cell of a woman and of a man. You will notice that the only differences are in the 24th pair which are the sex



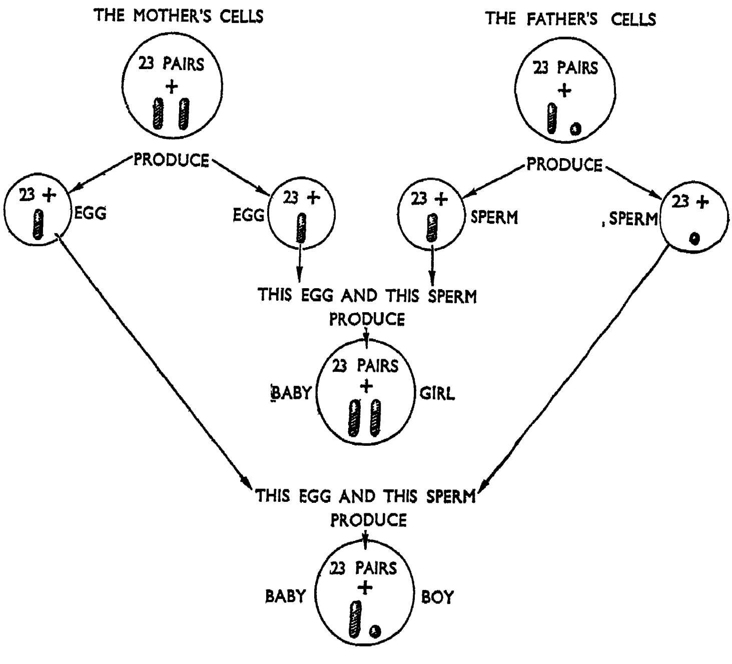
Chromosomes change from the necklace form and become short and fat at times, as shown in this drawing. The chromosomes within the small circles are the sex chromosomes

chromosomes. These sex chromosomes are of two kinds. The longer ones, (two in the female and one in the male) are called the X chromosomes, and a short one (only found in the male) is called the Y chromosome. When the sex cells are being formed in the ovaries and testes, the 24 pairs separate into two groups of 24. So every female egg cell contains an X chromosome but only half the male sperms will contain an X chromosome while the other half will contain a Y chromosome.

How the sex of a child is determined

When a sperm fertilizes an egg cell there are two possibilities:—

1. The egg cell may be fertilized by a sperm containing



How the sex of a child is determined

an X chromosome. The fertilized egg will contain XX chromosomes and will develop into a girl.

2. The egg cell may be fertilized by a sperm containing a Y chromosome. The fertilized egg will contain XY chromosomes and will develop into a boy.

Twins

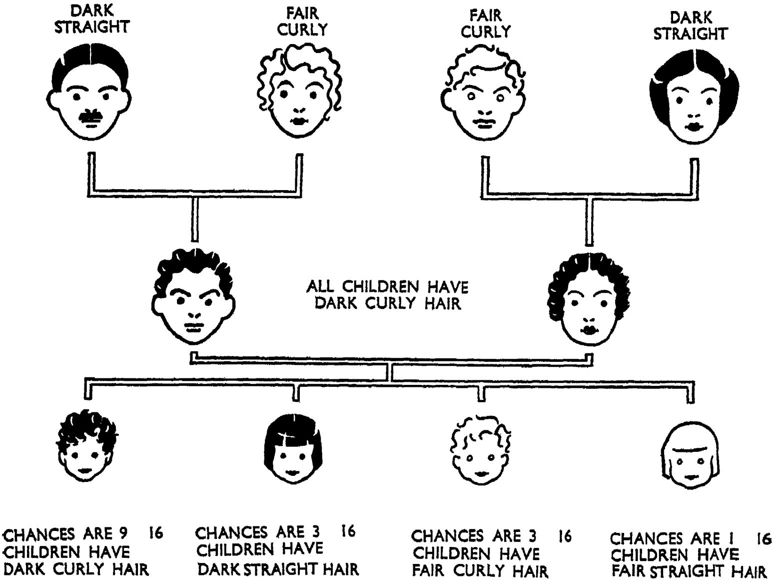
In some families the tendency to produce twins seems to be inherited. In the years during which a woman can have children, it is usual for one egg cell each month to be set free from her ovaries. If it is fertilized it develops into a child (Book II, p. 74). If it is not fertilized, it is washed out of the uterus, together with the skin lining the uterus, by the menstrual blood during her next monthly period. Occasionally two egg cells are set free at the same time and if they are both fertilized twins will develop. Because each twin has developed from a fertilized egg in the same way as a single child, such twins need not be of the same sex and they may be as different from each other in the characters they inherit as are ordinary brothers and sisters. On the other hand, sometimes one egg cell may be set free and fertilized and then immediately divide into two cells which separate from each other. They will develop into identical twins. These children will be of the same sex and will be very much alike in appearance and in other inherited characters. Very occasionally a fertilized egg may split into two and after these cells have separated, each may divide into two and these four cells may again separate. Then four babies will develop, all very much alike. They will be quadruplets.

SEX LINKED INHERITANCE

Sex linked inheritance in poultry

In poultry, the Light Sussex breed has silver feathers and the Rhode Island Red breed has gold feathers. If a Light Sussex hen (with silver feathers) is mated with a Rhode Island Red cock (with gold feathers) the chicks

HOW THE TYPE AND COLOUR OF THE HAIR MAY BE INHERITED



	Dark Curly	***Fair Curly***	Dark Straight	*Fair Straight*
Dark Curly	1 **DC**	2 **DC**	3 **DC**	4 **DC**
Fair Curly	5 **DC**	*1* ***FC***	6 **DC**	2 ***FC***
Dark Straight	7 **DC**	8 **DC**	1 DS	2 DS
Fair Straight	9 **DC**	3 ***FC***	3 DS	*1* *FS*

Dark hair is dominant to fair hair, and curly hair is dominant to straight hair One of each pair of parents in the top row of this drawing has "pure" dark straight hair and the other has "pure" fair curly hair. Their children in the middle row have dark curly hair but they carry the hidden characters for fair straight hair. They are said to be "hybrids" The lowest line of the drawing, and the table below, show how the characters may sort themselves out in the next generation.

which develop from her fertilized eggs are of two kinds. All the male chicks (cockerels) are silver and all the female chicks (pullets) are gold because the hen passes on the gene for silver feathers to her sons but not to her daughters. This fact is used by poultry keepers in order to sort out pullets and cockerels immediately they are hatched. You may like to look up other characters in poultry which are sex linked and so can be used for sexing chicks, in Bulletin No. 38 of the Ministry of Agriculture, Fisheries and Food. It is called *Sex Linkage in Poultry Breeding*.

Haemophilia

The blood of some men and boys does not clot quickly after a cut or even a scratch. For such people, any operation, or even a bruise, could cause death. This disease is called Haemophilia. It is passed on by some women who carry the gene responsible for this disease on an X chromosome. Such women do not suffer from the disease but pass it on to some of their sons. Queen Victoria was a carrier of this disease. One of her sons suffered from it and three of her daughters passed it on to some of their descendants, including the last Crown Prince of Russia and some of the sons of the former Spanish Royal Family. The factor has not been passed on to the British Royal Family.

Colour blindness

The gene for this condition is also carried on the X chromosome. If a mother has inherited this gene, she may pass it on to some of her sons. A few women are colour blind. This happens only if a woman has inherited

two X chromosomes which carry the gene for colour blindness.

BLOOD GROUPS AND THEIR INHERITANCE

You will know that in the treatment of certain diseases and sometimes after an operation or an accident, it is necessary to give a person a blood transfusion. You also know that many people regularly give some of their blood to a hospital for this purpose. It is important to use, in such cases, only blood which will mix with that of the sick person without causing the red corpuscles of his blood to stick together in clumps. At the beginning of this century it was found that a person might possess blood belonging to one of four main groups called A, B, AB, and O.

A and B contain two different chemicals, AB contains both, O contains neither. In Europeans, AB blood is the rarest type. Later, it was found that these blood groups are inherited. Nowadays it is considered safest to give a patient the same type of blood as his own, and this is done whenever possible.

The Rhesus factor

Most Europeans have a chemical in their blood as a result of an inherited Rhesus factor (so called because it was first found in Rhesus monkeys). Such people are said to be Rhesus positive. About one seventh of the population do not have this chemical and are Rhesus negative.

Let us suppose that a Rhesus negative woman is having a baby and the baby has inherited a negative gene from her. It may also have inherited a positive gene from its father. If this happens the child will be Rhesus positive because the positive gene is dominant to the negative one.

This means that the child's blood will contain a chemical which the mother's blood does not. You will remember that certain chemicals may pass from the developing child to the mother through the placenta (Book II). If this chemical travels to the mother's blood, her blood *may* produce antibodies as a result of the invasion of a strange substance. If the antibodies then travel to the child's blood they may destroy it. However, doctors now advise expectant mothers how to protect their babies against this. Should the baby's blood be damaged, its life may be saved by a replacement transfusion.

THE IMPORTANCE OF A GOOD ENVIRONMENT

Heredity deals only with genes passed on from generation to generation. No one can benefit fully from the good things he has inherited if his surroundings are not satisfactory. Parents who give their children a good home, encouraging them to take an interest in everything around them and helping them to do their best at work and to enjoy their leisure in a sensible way, are enabling them to make full use of their talents.

Bad surroundings and bad companions lead young people into crime much more often than does bad heredity. In fact, there is very little evidence that a criminal tendency can be inherited. On the other hand, low intelligence plus bad homes may together account for the record of the notorious Jukes family. In five generations, 300 members died as babies, 310 spent a total of 2,300 years in workhouses, 440 had chronic diseases, and 130 were criminals, including 7 murderers. Only 20 worked at a trade.

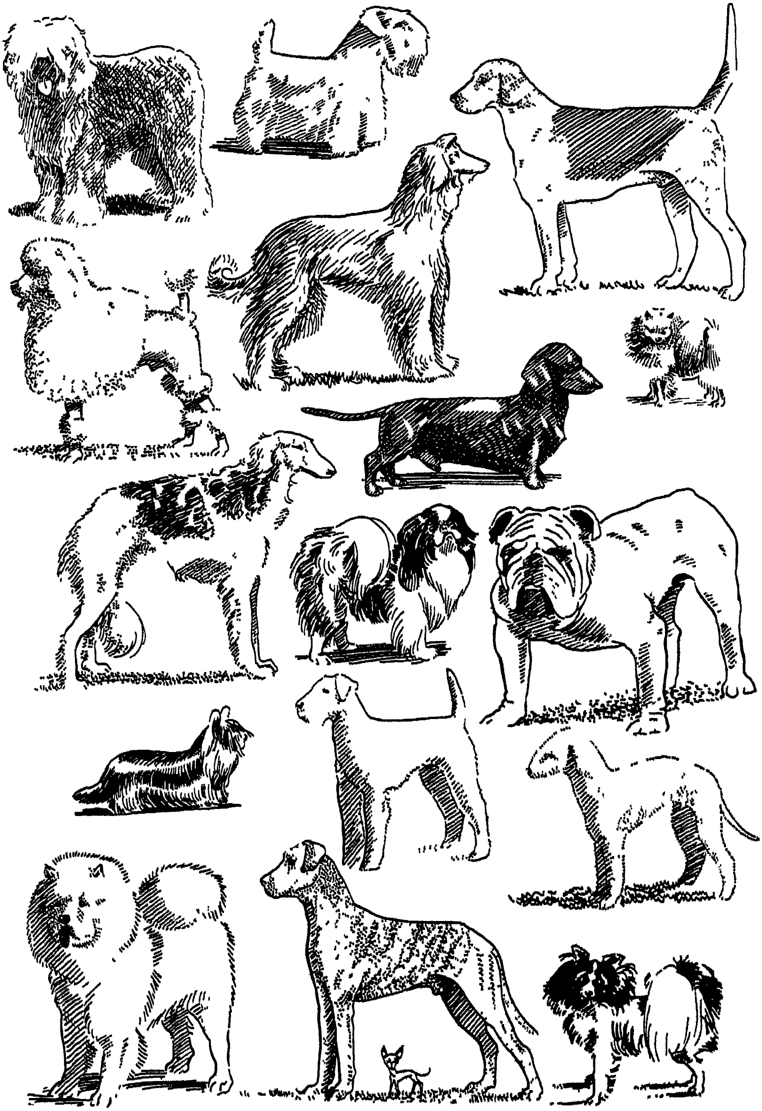
Can we inherit skills or injuries?

Some people imagine that a man who has trained himself and has become a first-class cricketer can pass on his skill to his son, and that the daughter of a tennis champion will also become a champion. This is not so. The child of an expert player must practise just as hard as his father had to do in order to acquire the same amount of skill. We cannot pass on qualities we have acquired during our lifetime. A man who has lost a limb in an accident does not pass on this injury to any of his children.

HOW SCIENCE HELPS PLANT AND ANIMAL BREEDERS

In Nature, the weaker animals tend to die out because they cannot obtain food or a mate as easily as can their more active brothers. Charles Darwin called this "Natural Selection by the survival of the fittest." For hundreds of years, animal breeders have carried out deliberate selection. They chose from their stock, animals which had a desirable character and bred from those. For example, a breeder of race horses would mate together horses having long legs and other qualities needed for speed. From the next generation he would again breed only from the best of his stock.

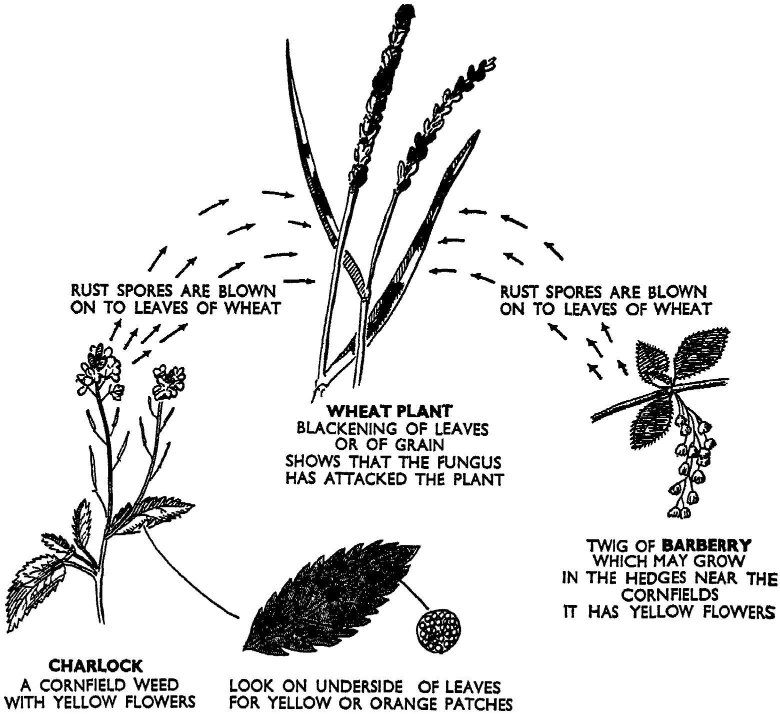
We have only to look at the variety of Man's domestic animals to see how successful the breeders have been. Beside the speed of the race horse there is the great strength of the Shire horse which used to plough all the cornfields. Dogs, too, have been bred for many different purposes; the little Fox Terriers, the Dachshunds (for Badger hunting), the great Alsatian police dogs and the Irish Wolfhounds. Cattle, pigs and poultry have all been



From top to bottom · Old English Sheepdog, Poodle, Borzoi, Pekinese, Chowchow, Sealyham, Afghan Hound, Dachshund, Chin Chin, Welsh Terrier, Great Dane, Chihuahua, Fox Hound, Pomeranian, Bull Dog, Bedlington Terrier, Papillon. All these different breeds of dogs have been produced by artificial selection.

vastly changed and improved by scientific breeding during the last two hundred years.

As characters are inherited according to definite laws it is often possible to obtain in animals and plants not only one but several desired characters. For example, some kinds of wheat produce a good yield but are easily attacked by the rust fungus which is a parasite on cereals and



spoils the crop. Some other kinds of wheat are not attacked by the fungus but produce little seed. By crossing these two kinds, strains of wheat have been produced which crop well and are resistant to the rust disease.

(The fungus responsible for rust disease in wheat needs

two host plants to complete its life history. For part of its life it lives on the green parts of a cereal plant and the rest of its life is spent on such plants as charlock (a cornfield weed), or barberry, which was used for hedges before farmers connected its presence with diseased wheat. This fungus cannot spread if such plants are kept away from cornfields.)

Many of our cultivated plants have interesting histories. The garden strawberry had very two different ancestors. One was a plant which produced very small well-flavoured fruits. It was brought from the woods of North America to Europe. The other had large juicy fruits but the flavour was poor. It came from South America. As a result of cross pollination, plants were produced which had large well-flavoured fruits. Our modern strawberries have developed from these by further breeding. We now know that both ancestors had 56 chromosomes.

Mutations

Occasionally a gene on one of the chromosomes in the cells of a plant or animal becomes changed. The changed gene will be present in some of the sex cells and so may be passed on to some of the offspring. The drooping stems of the Weeping Willow and the brown leaves of the Copper Beech tree are due to a changed gene. Brussels sprouts, cabbage, broccoli, cauliflower and other members of the cabbage group of vegetables were all produced in this way from the wild cabbage. A sudden change of this kind is called a mutation. A mutation occurred in the Peppered Moth which turned some of the offspring of a pair of moths black. You can now find black Peppered Moths, especially in smoky cities where the dark colour helps to protect them from enemies. Most mutations are, however,

harmful, and as a result the plant or animal with the changed gene dies, often without offspring. One of these mutations produced a seedless orange. In the wild state, this kind of orange would have died out, but as Man thought it a desirable form, it was reproduced vegetatively. (Book III, p. 178.)

An example of a harmful mutation in human beings is a change in the gene responsible for producing a chemical which causes blood to clot as soon as it is shed. The changed gene does not produce this chemical and so the disease of Haemophilia results.

Plant and animal breeders look for desirable mutations and by suitable crossing, try to combine them with other desirable characters. In this way new varieties of cultivated plants arise every year. The Sweet Pea flowers we know, with their large wavy petals and their variety of colours, have been produced by mutations from the smaller and less colourful flowers our grandparents can remember. Sometimes, however, it is impossible or difficult to breed from a plant or animal with a desirable mutation.

Abnormal numbers of chromosomes

Sometimes a sex cell is formed which has twice the normal number of chromosomes. If an abnormal pollen grain fertilizes a normal ovule the plant which develops from the seed will have one and a half times as many chromosomes as either of its parents and it may differ from the parents in other important ways. "Bramley's Seedling," one of our most useful apple trees, developed in this way. These apples keep well, cook well, have a pleasant flavour and more Vitamin C than other cooking apples. Unfortunately, it cannot often form normal pollen grains and ovules because it has 51 chromosomes instead

of 34 which is the normal number for apples. This odd number cannot be divided into two equal groups. However, these apple trees and other plants such as King Alfred Daffodils and some of the larger Hyacinths which also have an odd number of chromosomes, can be multiplied by vegetative propagation. (Book III, p. 178.)

Sometimes plants have twice as many chromosomes as their parents. Such plants are usually larger and sturdier than the parents and have larger flowers and fruits. A large Evening Primrose, some of the Chinese Primulas and two new kinds of pears are examples of such plants.

Changing the Chromosomes

Chromosomes may be altered artificially by X-rays, by heat, or by certain drugs, for example, colchicine. Plant breeders are already getting new varieties of plants as a result of research. Thus scientists are helping to give us better food crops and new and more beautiful plants in great variety.

PLANT FREAKS

In the last century, an American, Luther Burbank, made a collection of abnormal plants. He also tried to produce new kinds of plants by crossing those plants which looked as if they were closely related. The "Phenomenal berry" (resulting from a cross between blackberry and raspberry), a white blackberry, and an orange with thin peel were three of the novelties he produced. Another was a cactus without spines. In some parts of the world cacti will grow where hardly any other plants can exist. Burbank's spineless cacti can be eaten

by cattle and so his "freak" cactus made it possible for cattle to live in these dry areas.

Normal radishes (*left*) and radishes treated with the drug colchicine (*right*)
(*John Innes Horticultural Institute*)

TEN QUESTIONS ON HEREDITY

1. What do you understand by heredity?
2. Explain clearly how Mendel carried out his experiments
3. What is meant by a dominant character? What is a recessive character?
4. Say what you know about chromosomes.
5. How do the sex chromosomes determine the sex of a baby?
6. Name some characters inherited in human beings.
7. What do you know about sex linked inheritance?
8. How can parents help their children to make the most of the good factors they inherit?
9. How has science helped the plant and animal breeder?
10. What do you know about mutations?

THINGS TO DO AND TO FIND OUT

1. Make lists of the things you think you inherit from your Mother, your Father, and your grandparents.

2. Write down the height and the weight of each member of your class. These figures show the variation in height and weight of your class of pupils aged 14 to 15 years

3. If you can obtain a small branch of Snowberry (*Symphoricarpus*), you will find that the leaves are not all the same shape. Press or draw some of those which show variations in size and shape.

4. Examine the flower of a pea, bean or sweet pea. Look for the stamens and for the pistil consisting of stigma, style and ovary. (If you need help, refer to Book II, pp. 68–70, and Book III, p. 171.)

5. From an encyclopaedia or other book, find out all you can about the work of Luther Burbank, the "Plant Wizard." Your class might prepare an exhibition of specimens, drawings and notes to illustrate his work.

6. From nurserymen's catalogues, find out some of the new varieties of plants which are on sale for the first time this year. If you are lucky enough to know a nurseryman who has recently produced a new kind of plant ask him to tell you its history.

7. Make drawings of a group of related plants which may have developed by mutations from the ancestors of one member of the group: for example, apples from a wild crab apple. Show in what ways the modern forms are different from each other. Compare the flavour of different kinds of apple (including the crab apples). You might also experiment with the keeping and cooking qualities of different kinds of apple.

8. Collect pictures of as many breeds of dogs as you can. Label them, stating the approximate size, colour, and special characters of each. You might prepare class scrapbooks on dogs, poultry, cattle and horses.

9. If you know a pair of identical twins or a pair who are not identical make a list of ways in which they are alike and ways in which they differ. Find out if any of their relations are also twins.

10. Collect newspaper cuttings about, and pictures of families of quadruplets.

11. Try to find out something about the famous Dionne quins. Can you work out how a mother might produce five babies instead of one?

12 Find out from your grandparents which of our garden flowers were unknown when they were young

13. If any of you have racing pigeons, find out about the inheritance of speed of flight and of homing capacity of these birds.

14. The acorn and the runner bean seed are almost the same size, yet one develops into a forest tree while the other produces a plant which climbs and which lives only for one year. Make a list of other differences between an Oak tree and a Bean plant. Why do you think these two plants are so different?

15. Mice are useful animals for experiments on heredity. You will need to buy mice which belong to pure strains. These are slightly more expensive than those of mixed parentage. You might breed from a male albino mouse (with white coat and pink eyes) and a female mouse having a black coat and dark eyes. Repeat the experiment using a female albino and a male dark-coated mouse. Keep a careful record of coat colour, eye colour and weight of each parent. When a litter is produced keep a record of these characters in the young mice also. Weigh your mice each week until their weight is fairly constant. Keep a record of this weight.

16. Mate two mice from the litter obtained in Experiment 15. What do you notice among their offspring? Try to repeat these experiments several times. What can you say about inheritance of coat colour, eye colour and weight in the strains of mice you have used?

17. Try to find out by breeding whether the peculiar movement of "waltzing mice" is inherited. If you can obtain such mice from

a reliable pet shop, try to cross one with one of your other pure strain mice.

N.B.—EXPERIMENTS ON ANIMAL BREEDING MAY INVOLVE CRUELTY TO THE ANIMALS if you do not find out the best ways of housing, feeding and generally caring for them. The Universities Federation of Animal Welfare has published a book written by J. P. Volrath especially to help schools with work of this kind It is called *Animals in Schools*.

The dealer from whom you obtain your animals will tell you how to look after them and will probably sell you a booklet about their care

18. If you know people who keep pedigree pigs or poultry, ask if they will show you the records they keep. Say what you have learned from these records.

19. If you live near racing stables, you might get permission to study the pedigrees of some race horses. Can you explain any interesting facts you may notice?

20. Visit your nearest museum and look for exhibits which may help in your study of heredity; for example, exhibits of the results of breeding experiments with maize, wheat and other cereals.

21. If you live near a dairy farm, ask the farmer to tell you how cows are bred to obtain a plentiful supply of high-grade milk.

SOME BOOKS YOU MAY FIND USEFUL FOR YOUR WORK ON HEREDITY

A. Scheinfeld, *The New "You and Heredity."*

C. Bibby, *An Experimental Human Biology.*

M. Thomas, *Growing Up* (for girls).

J. B. S. Haldane, "*Science and Everyday Life.*"

The Encyclopaedia Britannica and other encyclopaedias.

(Teachers will find interesting articles on plant breeding in the journals of the Royal Horticultural Society. One such article is entitled "The Origin and Improvement of Cultivated Plants" and can be found in the November and December Journals for 1950.)

SECTION 3

Field Work

EACH OF US belongs to a family. We have close relations and distant relations. We also belong to a group or community of people who live in a certain place. We help other people in the community and other people help us in many ways. Have you thought how much you depend on others in your community: for example, your doctor and dentist; the men who collect refuse and those who provide gas, electricity, clean water or milk?

Plants and animals belong to families, and they also live in communities in which they depend on each other for food, shelter and protection from enemies. In any community, some animals feed on plants while others kill and eat other animals. Plants compete with other kinds of plant for room to grow, for light, for water and mineral salts. Some plants have advantages which enable them to crowd out other plant neighbours which lack these advantages.

The place where a community lives is called its habitat. The type of soil in one habitat may favour the growth of some plants more than of others. For example, Sheep's Sorrel grows better in more acid grassland than many other meadow plants, and so it frequently spreads in such areas while other plants are stunted. Heather and Heath will flourish in acid soils while many plants, normally found at the bottom of a chalk hill, would die if transplanted on to an acid heathland.

HABITATS SUITABLE FOR YOUR FIELD STUDY

Any place where plants and animals live can be used for your study. It is best to choose one near your school or near your home so that you can visit it often and at all seasons of the year. If you do this you will learn a great deal about the wild life of this area from first hand experience. You will learn most by careful observation and by keeping records of the work you do. Your field study can be a useful piece of research which can be continued in after years either by you or by other pupils of your school, so careful records of all you find should be kept. Some schools are near to a patch of waste land, disused allotments, or an overgrown bomb site. Some have hedges or fields nearby. Others are close to a stream, a pond or a small wood, while others are near the seashore, a heath, chalk downs, mountain or moorland. You could investigate part of the school field or a corner of the garden which is not cultivated. An overgrown path is a useful habitat to explore. The project on the Oak tree in Book I (pages 95 to 121) will help you to make a field study of the community of plants and animals associated with any tree. An Apple tree in the garden can be studied in just the same way as the Oak tree. If you decide to study the bird population of your street or of the park, the appendix to Book I (pp. 122 and 123) will help you to begin. Revise chapter 6 in Book I (Light and Life), and the project on the pond in Book II, if you wish to make a special study of a pond community.

Even if you live in the middle of a town, there is field study to do. A window box observed throughout the year, or work in the park might be possible.

STARTING YOUR PRACTICAL WORK

Your teacher will help you to choose a community to study. He may suggest that you and your companions divide up the work. Then, when you have finished, you will each report your findings to the rest of the class. You may then prepare an exhibition of work. Do not forget to collect everyone's results together and keep them.

Some useful things to do

Measuring distances out of doors. It is useful to know the length of your pace. Fix two pegs in the ground 100 yards apart. Then walk steadily from one to the other, counting your paces. Do this several times and take the average of your results. Divide 100 yards by the number of paces and this will give you the average length of your pace. Now you will be able to make a fairly accurate measurement of any distance over which you can walk, by counting your steps and multiplying this number by the length of your pace.

Reading an Ordnance map. Look at maps of your locality drawn to scales of 1″ to represent 1 mile and $2\frac{1}{2}$″ to the mile. If possible look at maps drawn to larger scales of 6″ to the mile and 25″ to the mile. Learn to recognise the symbols listed on the maps. Try to recognize the position of your school and other well-known landmarks. Ask your teacher for help if you need it.

Making a plane table survey. This will give you an idea of how maps are made. You will require the following:

Any flat board (e.g. drawing board, or a pastry board) size about 16″ × 20″, covered with a sheet of drawing paper.

1 ruler 12″ long.
4 long pins.
4 drawing pins.
2 wooden sticks for pegs.
1 sharp pencil.
1 small stool.

(Preferably the board should be fixed on a wooden tripod which might be made at school.)

First decide on the scale to be used. Divide the greater distance you wish to include in the map by the size of your paper. If that distance is 200 yards and your paper is 20″ long, then $\frac{200 \times 36}{20}$ will give a scale of 1″ to represent 360″, or 1″=10 yards.

Next, choose any clear level piece of ground from which many prominent landmarks of the area can be seen. On this ground measure a line: 100 yards is a convenient length. This is called the base line and is the base from which the whole survey is to be made. If there are not enough clearly visible objects such as trees marking the boundaries of the area then poles should be held vertically to mark selected places. The base line must be measured *carefully*. Fix a peg at each end of the base line and call these pegs A and B. (See diagram 1.)

Draw the base line accurately to scale on your paper. 100 yards to a scale of 1″ = 10 yards is 10″ This line should be drawn in the centre of the paper if the base line is in the centre of the area to be mapped but near the edge of the paper if the base line is near the side of the area. Fix a long pin at each end of the base line on the paper, marking the ends A′ and B′. (Diagrams 2 and 3.)

Place the drawing board so that point A′ is as nearly as possible above the peg at point A on the baseline along the ground. Then the board must be turned until the pins

MAKING A PLANE TABLE SURVEY

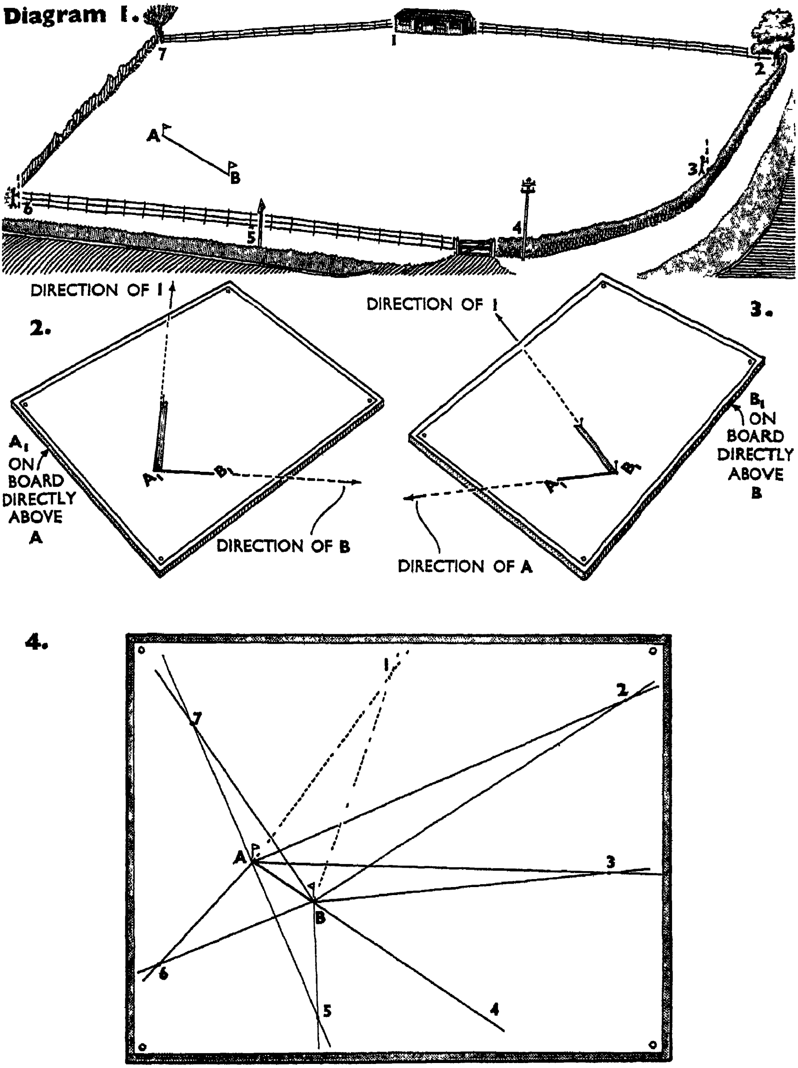


Diagram 4 shows all points plotted on the paper

at A′ and B′ make a straight line with the point B at the far end of the baseline on the ground. At each end of the ruler near one of the long edges, stick a long pin. Call these pins X and Y. Place the ruler with one end of its pin mounted edge touching the pin at A′. The surveyor then moves the other end of the ruler until pins X and Y make a line with some prominent object in the area to be mapped (see diagram 2). Draw a faint pencil line on the paper along that edge of the ruler and lightly write in the name of the landmark at the end of the line. In the same way sight as many landmarks as possible along the ruler and pencil them on the paper.

Then take the drawing board to the other end of the baseline and place it so that point B′ on the paper is as nearly as possible over the peg at B. Place the ruler against the pin at B′ and again sight along the pins at X and Y to the first of your previous landmarks (see diagram 3). Now draw a short line at the point where the ruler crosses the first line to that landmark. The place where the two lines cross is the position of that landmark on the map (see diagram 4). In the same way the whole series of points where two lines cross can be found and so the position of all the landmarks will be fixed on the map. The boundary of the area may now be drawn in.

There may be some points in the area which cannot be seen from the base line. Their position may be fixed either by using any two of the newly found points as a new baseline or by measuring along a sighted line from a known point. Every point should be fixed from as many observations as possible to ensure accuracy. All measurements should be done by chain or tape or by pacing.

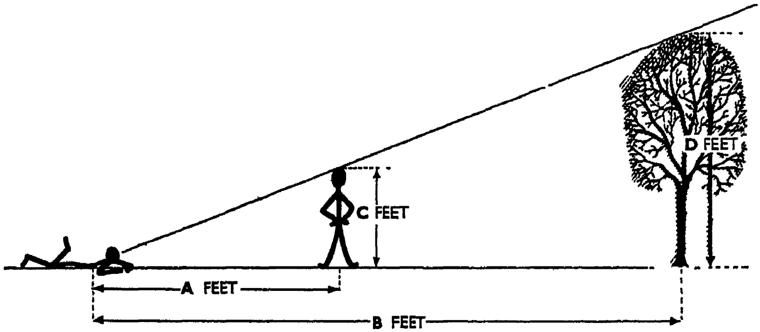
Note.—In the playing field shown in the diagrams, the telegraph post (4) was found to be the same straight line

as the base line A B. Its position was fixed by pacing from B.

Finding the approximate height of a tree. Ask a friend to stand about twenty paces from a tree. Then find a place from which, when you are lying on the ground, you can see the top of his head and the top of the tree in one straight line. (Keep your eyes close to the ground while doing this.)

Then make the following measurements:—

(A) the distance from your eyes to your friend's feet.
(B) the distance from your eyes to the foot of the tree.
(C) the height of your friend



Finding the height of a tree

In the drawing on this page, A = 6 ft., B = 50 ft., and C = 5 ft.

Suppose that the height of the tree is D ft.

Then $\frac{D}{50} = \frac{5}{6}$ ft.

that is, 6D = 250 ft.

therefore, D = $41\frac{2}{3}$ ft.

So the height of the tree is, approximately, 42 ft.

To find the girth of the tree use a long tape measure.

HOW TO IDENTIFY PLANTS AND ANIMALS

Labelled specimens on the school Nature Table and good coloured pictures will help you to identify the plants and animals you find. The best way, however, is to learn to use the tables or "keys" for this purpose in such books as Gaston Bonier's *Name this Flower* and J. Hutchinson's *Common Wild Flowers*, and *More Common Wild Flowers*. These are not expensive books and you may like to buy one of them. Study the introduction to *Common Wild Flowers*, and look up the meaning of words you do not understand in the glossary (list of words with their meanings) at the back of the book. Ask your teacher for help when necessary. If the book is your own, you may like to colour the pictures of plants as you identify them, if not, make watercolour drawings of the plants you find.

Some other useful books for help in identifying plants and animals are: *The Observers' Books* (of Trees, Wild Flowers, Birds, Pond Life, Fungi, Mosses and Liverworts, Fishes, Grasses, Sedges and Rushes, Insects and Spiders, Ferns, etc.) or the larger books in the "Wayside and Woodland" series. You may be able to borrow these, and books in the "New Naturalist" series, from your public library.

The "King Penguin" books on flowers and on fungi, and the Puffin picture books, also, have coloured pictures which are clear and accurate.

Collins' *Pocket Guide to Wild Flowers* has many excellent coloured illustrations.

The B.B.C booklets for school broadcasts in Nature Study and General Science and pamphlets on Water

Creatures, The School Aquarium and other topics, published by the School Nature Study Union, will also help you.

The naming of plants and animals

Every plant and every animal has two names. One is its common or local name; the other is the scientific name by which it is known in every country of the world. The scientific names are based on Greek or Latin and usually consist of two words. The first word tells us to which group or genus the plant or animal belongs, while the second tells us exactly which member of the group it is. You may like to think of this system of naming as being rather like our system of having a surname which all members of the family have, and a first name or Christian name, which only one member has. The Swedish botanist, Linnaeus, who was born in 1707, first named living things in this way.

The Creeping Buttercup is the common name for Ranunculus repens; the scientific name for the Bulbous Buttercup is Ranunculus bulbosus, and the white Water Buttercup (Crowfoot) is Ranunculus aquatilis. All the different buttercups, and other plants which seem to be related to the buttercups have been placed together in the family or Natural Order Ranunculaceae. The names of all the plant families end in the letters "ae." Here are a few points to help you begin to recognize members of some of the plant families:—

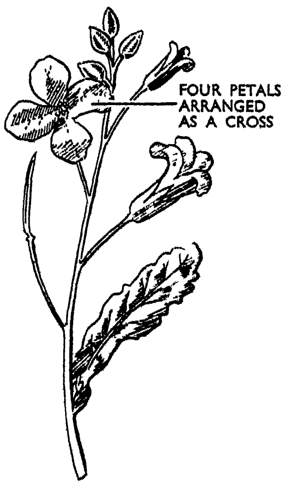
A. *Veining of leaves* will help you to classify plants.

Under the trees or in ditches you may find skeleton leaves. The soft green parts of the leaf have rotted, leaving the veins. Examine such a leaf with a magnifying

glass and draw what you see. You may be surprised to find that all leaves fall into one of two groups. In one group, the ends of the veins look like small twigs. This arrangement is called "open veining" and all plants belonging to the big group known as Dicotyledons (having two cotyledons in the seed) have this kind of leaf veining. The Oak tree, you will remember, is one of these plants.

In the other group, to which the bluebell and iris belong, the veins join up to form a closed pattern. This is "closed veining." The plants in this group have only one cotyledon in the seed (Monocotyledons).

Making skeleton leaves. Dissolve 4 oz. of washing soda (sodium carbonate) in 16 oz. of water. Boil, and stir in 2 oz. of caustic soda (sodium hydroxide). Cool and filter the liquid. Put in dead leaves (select undamaged ones) and boil gently for one hour. Wash the leaves thoroughly and dry with blotting paper. Press and beat gently with a stiff brush. The soft parts will drop out, leaving the pattern of the veins.



WILD CABBAGE (X 1)
(WASTELAND)
CRUCIFERAE

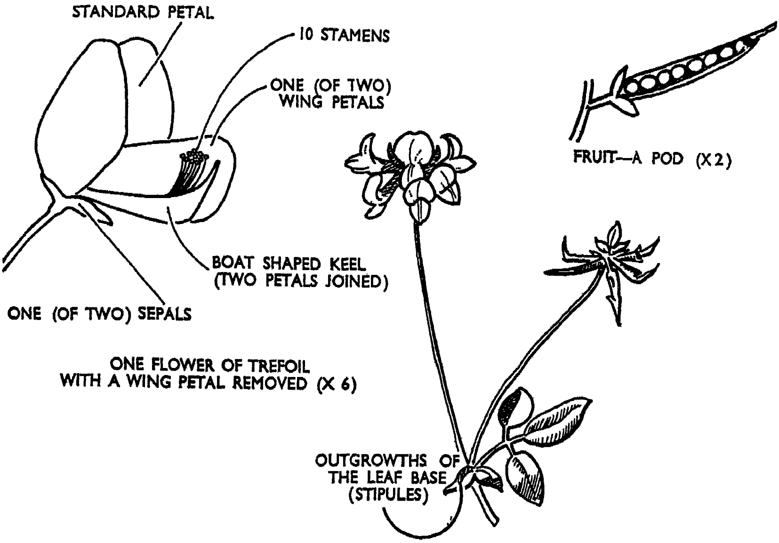
B. *Flower parts in 4's or 5's. Open veining of the leaves.*

DICOTYLEDONS

1. Flowers have four petals in the form of a cross

CRUCIFERAE

2. Flowers shaped like those of Sweet Pea or Bean. If small, they may be grouped in a head, as in Clover. Fruit is a pod. Leafstalks have outgrowths (stipules) LEGUMINOSAE



ONE FLOWER OF TREFOIL WITH A WING PETAL REMOVED (X 6)

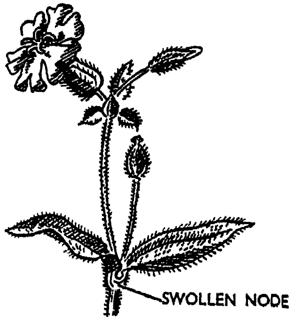
BIRDSFOOT TREFOIL (X 1)
(MEADOWS AND WASTELAND)

LEGUMINOSAE

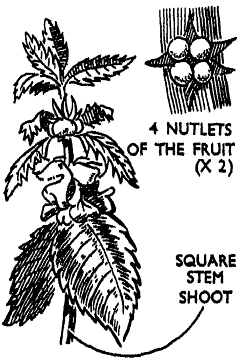
3. Flowers are cup or saucer shaped, with five petals and many stamens. Leafstalks have stipules ROSACEAE

4. The leaves are in opposite pairs on the stem. The place where they join the stem (called the node), is swollen, and the stem looks as if it is jointed. Usually there are five petals and ten stamens CARYOPHYLLACEAE

SILVERWEED (X 1)
(PATHS AND ROADSIDES)
ROSACEAE



WHITE CAMPION (X 1)
(WASTELAND AND HEDGES)
CARYOPHYLLACEAE



TOP OF WHITE DEAD NETTLE (X 1)
(WASTELAND AND HEDGES)

LABIATAE

OX-EYE DAISY (X 1)
(MEADOWS AND WASTELAND)

COMPOSITAE

5. The leaves, when crushed, have a "herby" smell, sometimes unpleasant. Most of these plants have stems which have four corners. The flowers have an upper and a lower lip. The fruit is four tiny nutlets arranged like a "hot cross bun" LABIATAE
6. What appears to be one flower is really a collection of tiny florets. The florets may be strap shaped, as in Dandelion, tube like, as in Thistle, or there may be some of each kind (Daisy) COMPOSITAE

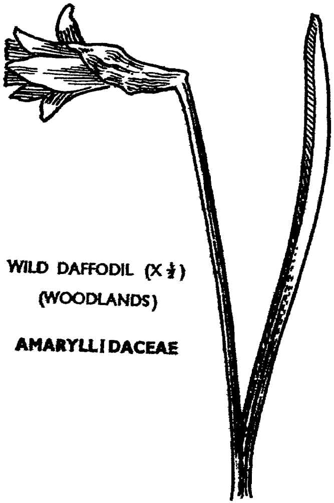
C. *Flower parts in 3's or 6's Closed veining of the leaves.*

MONOCOTYLEDONS

1. Flowers have six white or coloured parts which look like petals, and six stamens. The ovary is joined to the flower stalk above the bottom of the petals LILIACEAE
2. Flowers have six petal-like "perianth leaves" and six stamens, the ovary lies below the rest of the flower. Three of the perianth leaves may be smaller than the other three (in Snowdrop), or there may be a cup shaped "corona" as in Narcissus AMARYLLIDACEAE
3. Flowers have six perianth leaves and three stamens. The ovary is beneath the rest of the flower IRIDACEAE
4. Flower parts small and scaly, stamens hang out of the small flowers when ripe. Stigmas are feathery and catch pollen blown onto them by the wind. Leaves are long and narrow GRAMINAE

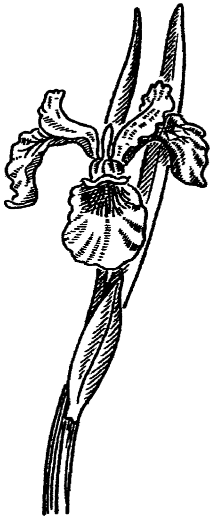
BLUEBELL (X 1)
(WOODLANDS)

LILIACEAE



WILD DAFFODIL (X ½)
(WOODLANDS)

AMARYLLIDACEAE



YELLOW FLAG IRIS (X ½)
(MARSHY GROUND BESIDE PONDS AND STREAMS)

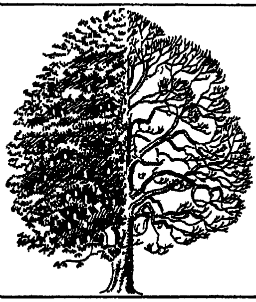
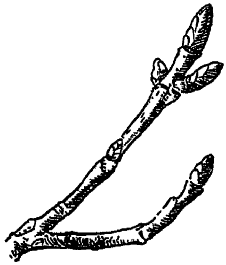
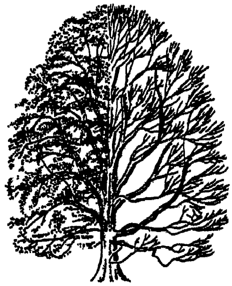
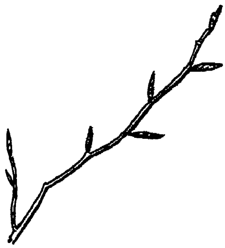
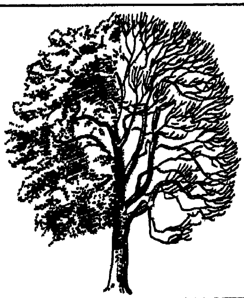
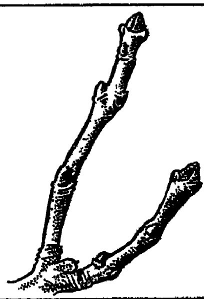
IRIDACEAE

COMMON OAT GRASS (X ¼)
(CULTIVATED LAND AND ROADSIDES)

GRAMINAE

Identifying trees.

From Book I you should be able to recognize an Oak tree at any season of the year. Here are drawings to help you recognize some of the other common trees. Find, and

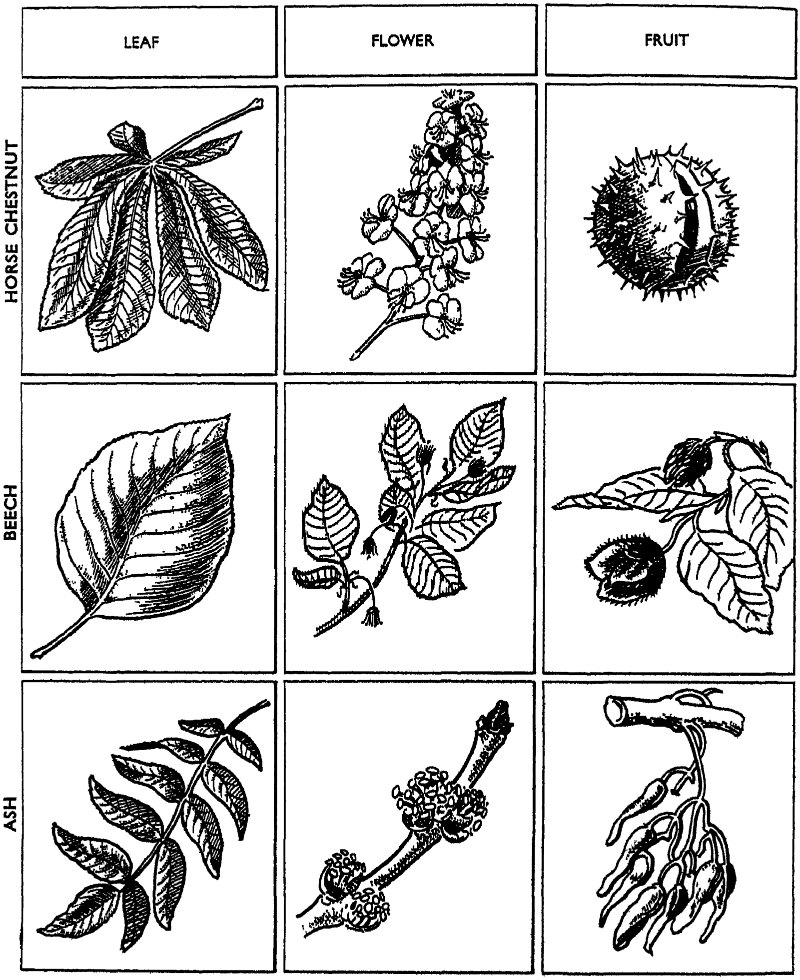
NAME	OUTLINE OF TREE SUMMER WINTER	WINTER TWIG
HORSE CHESTNUT		
BEECH		
ASH		

make drawings of two or three other forest trees near your home or school.

Two books which will help you recognize trees are:—

Makins, *British Trees in Winter*,

The Observer's Book of Trees.



MAKING A COLLECTION OF PRESSED FLOWERING PLANTS

You can preserve the plants you find by pressing them between sheets of absorbent paper. This will remove water slowly from the plants. Plenty of rough newspaper is useful because it does not dry the plants too quickly and so prevents shrivelling. You will also need a plant press made of two strong boards clamped together, or a pile of heavy books, a heavy box or some other flat object. For pressing delicate petals, you will also need a little cotton wool.

Collect not only the flower, but a shoot with a bud, a flower, and if possible, a fruit. If the fruit is too thick to press, draw it natural size, on paper. Also press flat a separate leaf, and if the plant has more than one kind of leaf, notice where each kind is found and press one of each. You will be surprised how many plants have one shape of leaf near the ground and at least one other kind on the flowering shoot. Many plants have interesting roots. If a plant seems very common in the area, press a root as well.

Use a whole newspaper for each plant. Fold it into two and into two again. Place the plant inside this folder, on the right hand side, and arrange it carefully. Pull out a small piece of cotton wool into a very thin layer and place it under the petals. Place another layer on top of the flower. Fold the left hand side of the paper over the plant and write on the outside the name of the plant, where and when you found it, and place the folder flat in the press. Several newspapers containing plants may be placed one on top of another under a weight. Examine your specimens after about a week. If they are not really dry, transfer each to a dry paper and press for another week. The

damp newspapers and cotton wool can be dried and used again.

Mounting the plants. Sheets of paper or thin card about 8 in. × 12 in. are suitable for mounting the specimens. Arrange all the parts of one plant on a sheet and stick them carefully, using a clear gum. Label any separate parts and stick on any drawings. Write on a label or directly on the top of the page, the name of the plant, its Latin name, its family name, and where and when you found it. For example:

> *Dog Rose*
> (Rosa canina)
> Family Rosaceae
> Found in a wood at Cuffley, Herts.
> June 15th, 19—.

Making a loose leaf book to supplement your collection.

For each plant in your collection, keep a whole page of paper punched, so that it can be included in a loose leaf book. On this page, note all the interesting facts you discover about the plant. Some of these things you will observe, others you may discover from books. You may find information about how the plant got its name, when and how it first came to this country, the kind of soil in which it thrives, and the communities of plants and animals in which you have found it. Many plants have interesting legends connected with them; some have been used for thousands of years as medicinal herbs. When the Romans conquered Britain they brought with them seeds of many of their native herbs. A number of

these for example, Borage, Rue, Celandine, Fennel and Thyme, flourished in these islands. You will find some interesting medicinal uses for many wild plants in the old Herbals, such as that written by John Gerard (1545–1607). A small modern book on herbs is the book *British Herbs* by Florence Ransom. It was thought that if a plant resembled an organ of the body, it would cure diseases of that organ. For example, the plant Lungwort has spotted leaves and was thought useful for curing lung disease. Extracts from the bright flowers of Eyebright were used for bathing sore eyes. Curious superstitions are associated with many of our wild plants. Can you discover by examining the plant, why the Devil's Bit Scabious was so named? Many plants formerly used to treat disease are now known to be useless for this purpose, but many others do provide valuable drugs. Deadly Nightshade and Woody Nightshade are two of these. Learn to recognise these plants from pictures. Most people confuse the Deadly Nightshade with the very common (but also poisonous) Woody Nightshade.

Many plants have interesting pollination methods which are worth observing and mentioning in your book. Some, such as the Ivy Leaved Toad Flax, have interesting methods of scattering their seeds. This plant turns its fruit stalk until the fruit is directed towards the wall on which it grows. When the ripe fruit splits, the seeds are shot into crevices where they germinate. Some plants have abnormal ways of living. The curious parasite, Dodder, lives on Gorse bushes and on leaves and stems of several other plants. It has no green leaves and so cannot make food for itself. Instead of roots, it has suckers which penetrate the stems of its host plant and absorb food and water from the host. Its fine red thread-like stems spread all over the shoot of the host. Can you find

a Gorse bush which is covered in July and August with many little pink balls of Dodder flowers? Parasites need to produce many seeds because very few will germinate near to a plant which will serve as a host, and even fewer of the seedlings can produce suckers which penetrate a host plant during the short period of a few days while the seedling is using food from the cotyledons of the small seed.

Preserving seaweed. Seaweed should be washed in fresh water to remove salt. Press brown seaweeds lightly between sheets of blotting paper to remove excess water and then press in newspaper and mount as for flowering plants.

The delicate red and green seaweeds can be floated on to paper or thin card. Place a card beneath a piece of weed in a large bowl or sink. Keeping the paper almost horizontal, gradually raise it up out of the water, spreading out the weed with a darning needle as you do so. Drain off the water and allow the paper to dry. The gum or mucilage produced by the drying seaweed sticks the weed to the paper. When dry, press the sheet flat under a heavy object.

Certain seaweeds are easily identified from coloured pictures in books, but you will probably need to visit a museum to compare your specimens with named ones. If you belong to a Natural History Society outside school, or to a Field Club, one of the members may be able to help you.

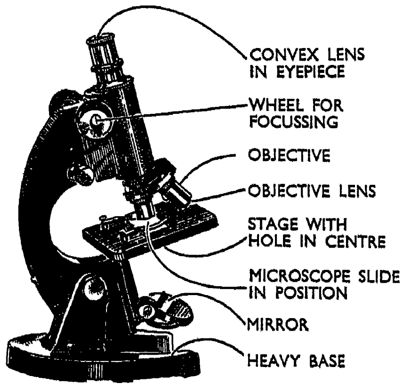
Preserving Mosses. These may be pressed in the same way as flowering plants. You will need a magnifying glass to help you identify them. A good reference book is the *Observer's Book of Mosses and Liverworts*, by Jule. You

can make a moss garden by arranging fresh mosses in a shallow dish or glass tank covered with a sheet of glass. Keep them moist and they will continue to grow. You can then watch them over a long period. Look for the fruits which are capsules on stalks. They contain spores (Book II, p. 69). When the spores are scattered they germinate on the moist ground and produce green branched threads like hairs. Buds on these hairs grow into moss plants. If you make a study of mosses, you will find that some, for example, the bog moss, Sphagnum, are found only in boggy places. Others are found only in damp woods and hedges while others grow on chalk downs. Each moss is a member of a community and cannot survive just anywhere.

Fungi. These are not easy to preserve. Instead, collect some in autumn and arrange them in a bowl with dead leaves and twigs from the habitat. Try to name them from such books as the books on *Poisonous and Edible Fungi* by Professor Ramsbottom. Draw and paint some of the toadstools. Notice that you find certain toadstools growing under Beech trees, others on manure heaps, others under Silver Birch trees, some on grassland, others on dead wood or tree stumps. Hunt among leaf-mould beneath forest trees. You may find white or pale coloured threads which are the underground parts of fungi. It is a curious fact that many forest trees depend on these threads for obtaining enough water. The threads penetrate into tiny holes in the bark of old roots and pass water from the soil into parts of the root which are too old to bear root hairs. It is thought that the tree passes soluble food to the fungus. In this way, the tree and the fungus help each other to obtain food. Such a partnership is called symbiosis.

Using a magnifying glass. In Book I you learned to use a magnifying glass which is a simple convex lens. Always carry a magnifying glass with you when you are examining plants or small animals. Carry it on a cord round your neck so that you can use it quickly without fear of losing it. Your magnifying glass will probably magnify about ten times. If you wish to see very small objects such as tiny pond creatures, spores or scales from a butterfly's wing, you will need to use a microscope which magnifies very much more.

Using a microscope. A microscope consists of a tube with a convex lens at the bottom and another at the top. In most microscopes the lower lens is fixed in a removable mount called the objective, and the upper lens is mounted in a tube called the eyepiece. There are often two eyepieces labelled $\times 8$ and $\times 10$. This sign tells you how many times the eyepieces will magnify the image of an object already magnified by the objective lens. There may be two or three objectives labelled 1 in., $\frac{2}{3}$ in. or $\frac{1}{6}$ in. or some other fraction of an inch. This means that the focal length of the lens (that is, the distance from the centre of the lens at which rays of light come to a focus) is 1 in. or $\frac{2}{3}$ in. or $\frac{1}{6}$ in. The smaller the focal length, the more convex the lens is, and the greater will be its magnifying power. When you are using the microscope with a 1 in. objective your specimen will be 1 in. from the centre of



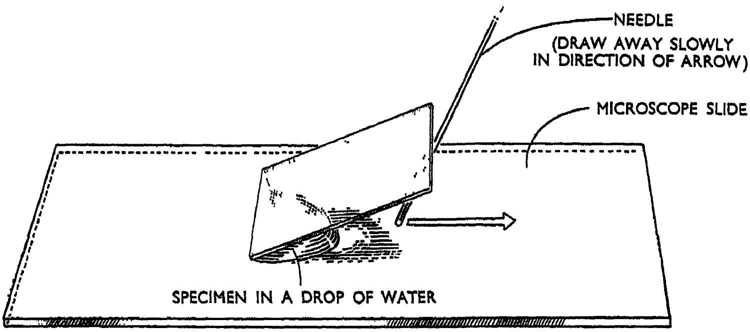
the lens when it is clearly focused. We call lenses of $\frac{2}{3}$ in. focal length or more, low power lenses and those with smaller focal length, high power lenses. Sometimes a microscope is provided with a $\frac{1}{12}$ in. lens. This is used only by advanced students for magnifying bacteria and chromosomes and other minute objects, and great care is needed in using it. The microscope has a heavy base by which it should be lifted. Beneath the tube containing the lenses is a flat stage. In this there is a central hole through which, by tilting a mirror, light can be directed on to the object placed on a glass slip on the stage. The flat side of the mirror is for use in artificial light, and the concave side is for use in daylight. Look down the tube and tilt the mirror until you see a bright circle of light. When this happens you know that light falling on the mirror is being reflected up through the stage on to the object you wish to magnify.

For focusing, most microscopes have wheels attached to a screw which moves the tube up and down. The large wheels are used for focusing the low power objective and the smaller wheel is moved very slightly in order to focus the high power objective. When you use the low power objective, the higher eyepiece is needed; for the high power objective, use the eyepiece marked with the lower number. Microscopes are made in such a way that this arrangement gives you the best results.

Any object you wish to magnify must be very thin so that light can pass through it. If the object is too thick, no clear image can reach your eye. Tiny objects such as pollen grains, scales from a butterfly's wing, moulds, and microscopic pond creatures may be placed on a clean glass slide in a drop of water and covered with a slip of very thin glass. If air bubbles are trapped under the coverslip, they will appear as black or grey circles. For

magnifying thicker objects, sections may be cut using a botanical razor or a razor blade mounted in a handle.

For observing moulds or fern spores, soap solution or glycerine is better than water for mounting the specimen on the slide because these solutions have lower surface tension than has water, and the tiny spores are not



Mounting a specimen for the microscope

drawn together as they are by the surface film of water. When looking at textile fibres under the microscope, mount them in paraffin oil.

If you are allowed to use the microscope, take great care of it. If you accidentally spill water on the stage, wipe it up at once. Clean the lenses by wiping them with a special chamois leather used for cleaning spectacle lenses.

Steps to take in using a microscope. 1. Mount the specimen in water on a microscope slide and cover it with a glass slip as shown in the diagram. Make sure that you always use a coverslip.

2. With the low power objective and the correct

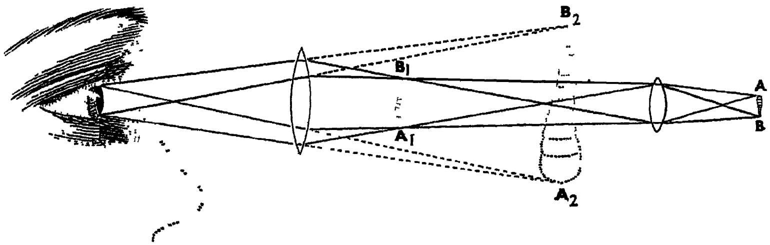
eyepiece in position, look down the tube and tilt the mirror until you see a bright circle of light.

3. Place the slide in the middle of the stage and slowly turn the larger wheels until you see the object clearly. Always begin with the low power objective.

4. When you have seen as much as you can with the low power objective, you may wish to replace it by the high power objective. Without altering the position of the tube, turn the disc until this objective comes into position, or unscrew the low power and replace it by the high power.

5. Very carefully focus the object by turning the small wheel slightly.

How a magnified image of the specimen is formed. Look at the diagram and find the object AB. Trace the rays of



How a magnified image is formed by a microscope

light from A and B as they pass through the objective lens and are focused at B_1A_1 to form a magnified image of the object. The eyepiece lens now uses this image as an object to be magnified still more, and the new enlarged image is formed at B_2A_2. This is the image you will see.

It is upside down. You can find out why this is so by revising the work on lenses in Book I, p. 62, and Book III, Chapter 8. If you turn the slide so that the object is upside down, you will see the image the right way up. To avoid eyestrain, keep both eyes open when you use the microscope.

WORKING ON AN AREA

Here is an example of the work you can do:

1. Measure the area by pacing and make a large map of it on graph paper.

2. Note which plants are plentiful in the area, which are fairly common, which are occasionally found, and which are rare.

3. Mark on the map any hollows, ridges and other features of the ground.

4. One small group of pupils might map the area covered by the most common plant: for example, in a wood, this might be Bluebell. Another group might map a plant which is fairly common, for example Wood Anemone. Other groups might map other plants found. Use water colours to paint the areas occupied by the different kinds of plants. Trace the results of all groups on to one map. Notice where the areas occupied by the various plants overlap.

5. Look carefully at the areas where two or more of the most abundant plants overlap. Which plant seems to be more successful than others? Which seems to be less successful? Are there signs that one is flourishing at the expense of another? Try to discover why this is so. Here are some possible reasons:

(*a*) One kind of plant may be taller than another, and

shut off the light from the shorter plant. (Why should this cause the shorter plant to die?)

(*b*) One kind of plant may have larger, spreading underground stems (rhizomes) or a larger root, or roots at two levels and so obtain water and mineral salts from both the surface layer of the soil and also from a deeper layer. One kind of plant may have underground parts which store much food while another may have no underground storage organ.

Competition among plants of an area

Where one kind of plant seems to be invading the territory of another,

(*a*) Measure the height of each kind of plant.

(*b*) Take a typical example of each. Remove all the leaves of each plant in turn and place them side by side on graph paper and draw round them. In this way you can find the approximate total leaf area of each plant. What do you discover?

(*c*) Carefully loosen the soil round the roots of competing plants. Try to dig up one of each kind without breaking the roots. Measure the rooting depths and enter them in your note book.

(*d*) Carefully uncover any underground stems (rhizomes, bulbs, corms, etc.). (Book III, pp. 178–9.) Try to discover how far one plant spreads beneath the ground and how many green shoots arise from it. Try to map the area occupied by one plant, on graph paper. You will need a ruler, pencil, graph paper, note book and stiff card or a board on which to rest your paper.

(*e*) Feel the top soil with your fingers. Is it gritty or sticky? Write down its type (see below).

(*f*) Test the soil with soil indicator (Book III, pp. 159–61). Record your result.

Identifying soils.

If gritty soil can be formed into a ball, it is a loam soil. If it cannot, but remains as separate grains when you try to roll it between your fingers, it is a sandy soil.

If sticky soil can be rubbed smooth between thumb and first finger, it is clay soil. If not, it may be silt.

Animals in the bark of a dead tree

Search in the bark of a dead tree stump or of a fallen tree for animals living or resting there. Collect them in a tin and sort them into insects (Book I, p. 114) and other creatures. Try to identify them from reference books, and make short notes on their life histories and their food.

Animals among the leaves of trees

Spread a ground sheet or sheets of stiff paper on the ground beneath a tree and beat the lower branches gently with a stick. Collect the creatures which fall to the ground and try to identify them. Note the number of each kind. Which of these creatures appear to depend on the tree for food or shelter?

Animals among the plants of meadow, wasteland or park

Look for creatures among the plants occupying a square yard of soil. Note where you find each animal. Try to discover its connection with the plants.

Animals in the soil

Mark out on the ground an area of one square foot. Note the plants growing in this area. Remove the top inch of soil and spread it out on a large sheet of thin white

Pupils using an auger, and testing the soil with the chemical indicator
A quadrat frame is beside the girl on the right

paper (kitchen paper is suitable). Crumble or sieve the soil and collect all the small animals you find. Put them in a collecting tin for identification later. Place a sample of the soil in another tin and label it "first inch." Before shaking the rest of the soil from the paper, test some of it with soil indicator. (Book III, pp. 160–1.)

Remove the second inch of soil and repeat this procedure. Continue to remove one inch of soil at a time,

collecting the animals found in it, and testing with soil indicator, until you have reached a depth of ten or twelve inches. Record your results as in this table, or think out a way of your own:—

Investigation of one square foot of soil on the North side of an Oak tree, 6 to 7 feet from the trunk.

Depth	Type of soil	Result of testing with indicator	Animals found
0–1″	Leafmould	Green colour, neutral soil	4 spiders
1″–2″	Leafmould	Yellowish green slightly acid soil	6 spiders many ants 2 woodlice
2″–3″	Dark, sandy soil	Yellow Slightly acid soil	5 pupae 2 beetles
3″–4″			

What have you discovered from this work? Compare your results with those of your classmates working on other sides of the tree or near other kinds of tree.

The soil around a tree

When you are studying the plants and animals associated with a tree, you may like to explore the soil beneath the tree. Here is one way of doing this. If you can think of other ways, try them out.

Tie one end of a rope round the trunk of a tree. Stretch out the rope on the North side of the tree and mark it at intervals of one yard, starting from the tree. Note the plants and animals, dead leaves, etc., which you find along

each yard of the rope. In the centre of each yard, take the soil temperature at a depth of 1 in. and also test with indicator for acidity. Examine the soil in each section, feel it, and write a few words to describe it. How deep is the layer of dead leaves beneath the tree? With a trowel, carefully remove the soil along the line to a depth of 3 in. Note what creatures you find in each section.

Repeat these observations on the South, East and West sides of the tree.

Measuring one square yard of ground

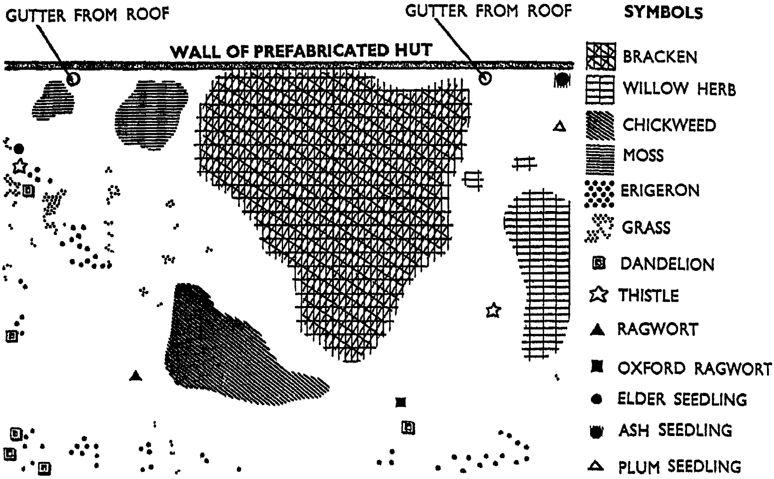
It is sometimes useful to have a quick and easy way of marking out one square yard of ground for investigation. One way of doing this is to use four 6 in. nails and a length of string or tape 13 ft. long. First tie the string firmly round one nail, close to the head. Measure one yard along the string from the nail and mark with Indian ink. Tie the string round the second nail at this point. Repeat, using the third and fourth nails. With a set square make a right angle at each nail. Then keeping the string taut, a square will be completed when the end of the string from nail 4 is tied round nail 1.

A square used for field study is called a quadrat. Squares with sides of one yard, of one foot or of six inches are sometimes used.

Using quadrats for field study

Quadrats may be used for studying the plants and small animals of any habitat except a hedge, a ditch, or a place where there is much water. A permanent quadrat can be made by fixing rope to wooden pegs driven into the ground. This is useful for studying a square yard of vegetation

throughout the year. This is a good exercise because it will show you the succession of life which occurs as the seasons change. Obtain permission to mark out your quadrat in the school garden, on a piece of waste-land, in a wood, in a meadow, or in a wild corner of the



park. If you wish to work in the park, it will be best if your teacher enquires from the local Parks' Superintendent whether this is allowed. Be careful to do no damage to trees or other plants. Here are some of the things you may study:

1. In the metalwork room, make a quadrat frame, with internal measurements of 3 ft. × 3 ft., from $\frac{1}{4}$ in. iron rod obtainable from a builder's merchant. To prevent rusting, paint it with aluminium paint. Another way is to make a frame from $\frac{1}{2}$ in. × $1\frac{1}{2}$ in. timber fixed together at the corners with $1\frac{1}{4}$ in. × $\frac{1}{4}$ in. cabin bolts and wing nuts. These frames are more convenient than the nails and string frames if you wish to record the plants

in several quadrats in a row, for you can move the rigid frames about quickly.

2. In Spring, map the plant shoots in a quadrat. For this purpose it is necessary to divide the sides of the quadrat into feet and to mark the divisions with Indian ink or paint. Then tie string across the quadrat from each marked point, dividing it into nine smaller areas each 1 ft. square.

3. In September, remove all litter (fallen leaves, twigs, etc.) from the quadrat. One week later, remove the litter which falls during that week, and repeat this every week for as many weeks as possible. Each week make a list of your findings, for example, beech leaves, sycamore fruits, twigs, and weigh the litter on a household balance or spring balance. Record the weight. If you can keep results for a year, you will be surprised at the weight of litter which falls on the small area.

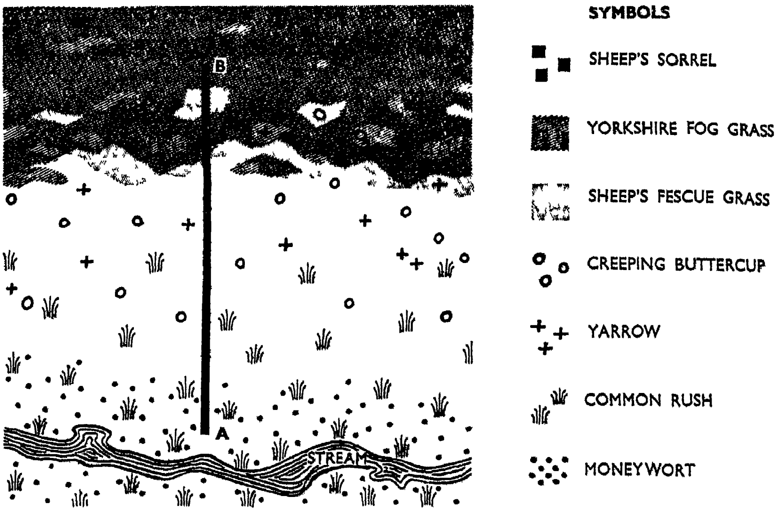
Can you think what normally happens to the litter? In how many different ways could it be removed? Try to find out by observation and from the experiments in Book III, pp. 181 and 182.

On graph paper divided into 1 in. and $\frac{1}{10}$ in. squares, draw a square with sides 3 in. long. Divide it into nine 1 in. squares. You now have a map of the quadrat to a scale of 1 in. represents 1 ft.

In each small square of the quadrat, note which plants are present and the amount of the square covered by each. Map them on the graph paper, using a symbol to represent each plant. Repeat this at intervals of 3 months. Opposit is a map of a larger area of wasteland near a school in London.

Let us suppose you wish to find how the kinds of plants and the acidity of the soil change as you move up a slope. Here is a plan of a small piece of wasteland in North

London which slopes down to a narrow stream. AB is a 50 yd. measuring line pegged to the ground. A preliminary survey of the plants in the area shows that the plants which are most frequent are Common Rush,



Map of a small area of Hampstead Heath

Moneywort, Creeping Buttercup, Sheep's Sorrel, Sheep's Fescue grass, Yarrow, and Yorkshire Fog grass.

You would place one side of your frame along the measuring line, as near as possible to A. Look carefully at the plants inside the square and make a list of their names. Do not count the number of each. Head your list "Plants found in quadrat 1 at the bottom of the slope." Test the soil in the middle of the quadrat with soil indicator.

Keeping your frame alongside the measuring line,

turn it over to cover the next half yard square of ground. List the plants in quadrat 2 and test the soil. Repeat for quadrats 3 and 4. Now miss out 20 quadrats. This is easily done by turning the frame over and over, counting as you do so. You will now be 12 yards from A. Examine four more quadrats, and complete your lists for these, calling them 5, 6, 7 and 8. Continue up the slope, missing out another 20 quadrats, then examine four more (9, 10, 11 and 12). Repeat until you reach B.

Here are some results for the land sketched on p. 102.

Soil Feeling test. Muddy by the stream Sticky, but cannot be polished Probably *silt*

At the top of the slope, the soil is gritty and cannot be rolled into a ball *Sand* grains are easily seen.

Plants	Found in quadrats																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Moneywort	—	—																		
Common rush	—	—	—	—	—	—	—	—												
Yarrow							—			—	—	—								
Sheep's fescue										—	—	—	—	—	—	—	—	—	—	—
Sheep's sorrel															—	—	—	—	—	—
Buttercup			—	—	—	—	—	—	—	—	—	—								
Yorkshire fog										—	—	—	—	—	—	—	—	—	—	—
Colour of soil indicator	yellowish green								yellow							orange				
Soil reaction	Slightly acid								Slightly acid							Fairly acid				

From the chart, answer these questions:—

1. Which plants grow only on the wetter soil?

2. Which grow only on the drier soil at the top of the slope?

3. Which plants can live in fairly acid soil?

Try to find a piece of sloping ground and work out results in this way. Of course, you will record the plants which you yourself find and make your own sketch map of the area. Note in which direction the slope faces. If you are fortunate enough to be able to study the slopes on each side of a small valley, compare the results from both slopes. How does the South slope differ from the North slope or the East facing slope from that facing West?

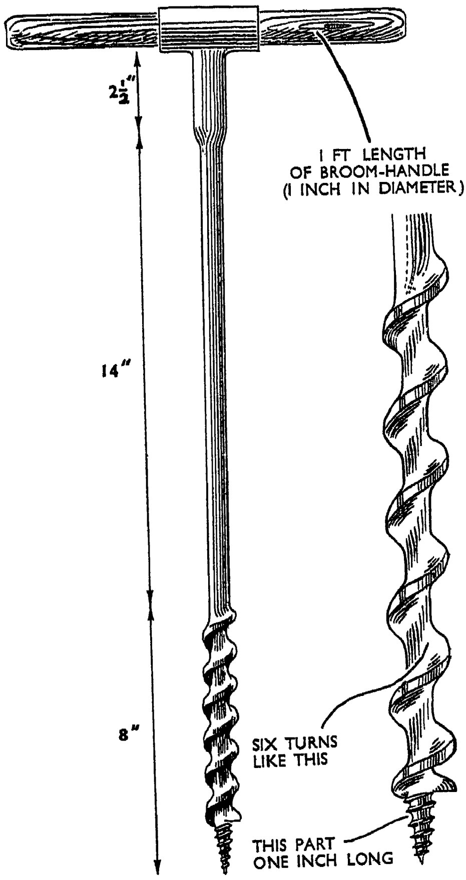
Soil temperatures

Revise the work on soil temperatures in Book III (pp. 166 and 167). In preparation for work in the field obtain a 6 in. nail which is about $\frac{1}{4}$ in. in diameter. Measure 1 in. from the point of the nail and make a mark about $\frac{1}{8}$ in. wide with enamel. Make other marks at intervals of 1 in. up the nail. When ready to take soil temperatures, push the nail into the soil up to the 1 in. mark. Remove the nail and carefully place a thermometer in the hole. The bulb will rest at a depth of 1 in. in the soil. After ten minutes remove the thermometer and read the temperature. Repeat this at a depth of 3 inches. Compare the results. If you are studying the plants on a slope, take soil temperatures in the middle of each quadrat. Try to obtain such temperatures on both dull and sunny days, when the soil is wet and after a week of dry weather, and at each season of the year. What do you learn from these results? Compare them with readings of air temperatures taken at the same times.

Making a Soil Profile

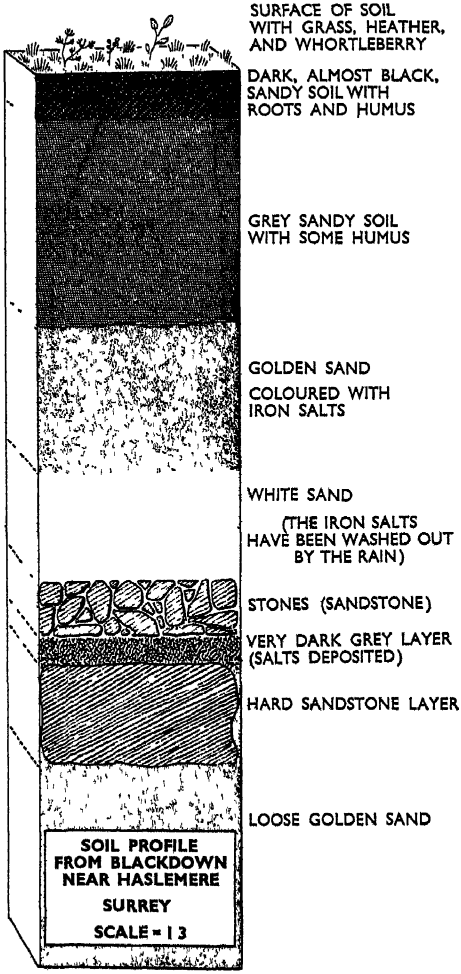
If your school has a 1 in. wood auger (a tool used by carpenters for drilling holes) you can use it for obtaining

samples of soil from the surface down to a depth of about 18 inches. (If you have no auger you can use soil collected as in the investigation described on p. 97.) Screw the auger into the soil at the selected spot and lift out the top three inches of earth. Carefully remove the earth from the auger and put it on a piece of paper marked No. 1.



A wood auger (useful for boring into soil)

Screw the auger down the same hole for a further three inches and again lift out some earth and put it on another piece of paper marked No. 2. Go on down in this way, putting each sample of earth on a numbered paper.



Take the samples back to the Science Room. You will now need a piece of wood, 18 in. long, 2 in. wide and about ½ in. thick. You will also require some glue which will stick damp earth to wood. (One of the new plastic glues which you mix with water such as "Casco" is good for this purpose.) Take a pencil and draw lines, 3 in. apart along the length of the wood. Paint the first 3 in. division with glue and sprinkle earth on it from the paper marked No. 1, until the wood is well covered. Paint the next division of the wood and sprinkle earth on it from the paper marked No. 2. Go on in this way until all the divisions on the wood are covered and the earth from all the pieces of paper has been used. (Be careful not to let earth fall on any but its own proper division on the board.) Make the soil profile look more realistic by glueing to the top of your piece of wood some plants from near the point where the auger was used. You will now have, on the wood, a profile or picture of the soil as it is down to a depth of 18 in. beneath the place where you tested it. Label your profile to show where the soil was collected.

You can see the layers of earth and rock in the sides of a quarry or in a new railway cutting: in fact, in any place where workmen are digging into the ground.

STUDYING A POND

First revise the project on a pond in Book II.

Make a sketch map or a more accurate plane table survey of a pond. Next collect one specimen of each kind of plant and animal you can find in the pond. (Book II, pp. 171–3.)

Take them back to school in pond water. In the Science Room, place each in a separate jar of pond water and try

to find the name of each from reference books and pamphlets such as those listed below or any others you can find. Make a name card for each jar.

You will find three types of pond weed:—

1. Those which float on the surface of the water, such as Duckweed and Frogbit (drawings in Book II, p. 156).

2. Those which have part floating above the water and quite a lot of the stem underneath the water. Water Crowfoot is an example of this type, and you will see from the drawing (Book II) that it has two different kinds of leaf. Can you think why this is useful to the plant?

3. Those which are completely covered by water; for example, Canadian Pondweed and Water Milfoil. Notice the shape of their leaves.

In order to see these plants clearly, tie a small stone or a thin strip of lead sheet to the broken stems of plants in this group and carefully lower them into gas-jars of water. The plants will then be anchored and will spread out in the water.

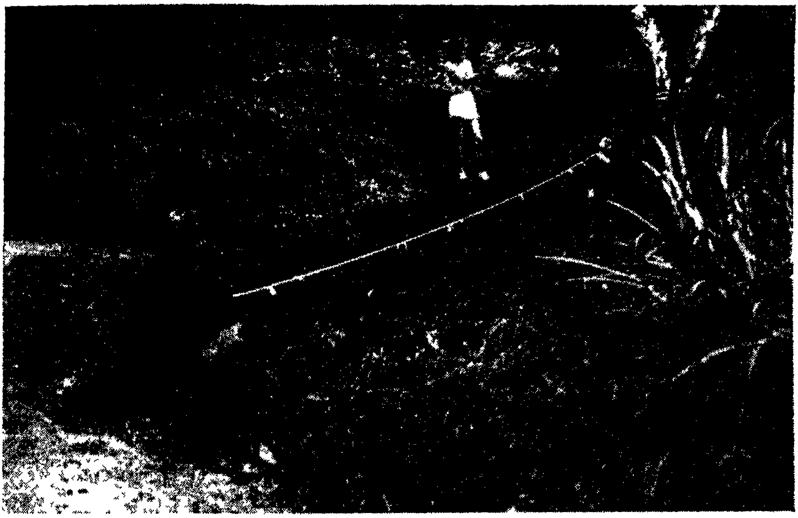
Mark on your map where each kind of plant and animal was found. You will need to use symbols for this.

If your teacher is sure that the pond is shallow and that the soil at the bottom is firm, you may like to construct a transect across the pond from A to B.

You will need a yard rule; and a pair of plimsolls to protect your feet from broken glass or sharp stones.

Get two friends to stretch a line, marked in yards, from A to B. Walk along this line, and use your long rule to measure the depth of the pond at each mark. Call out each result for a friend to record. Say which

plants and animals you find at each place where you measure, and record them also. When you return to school, draw the section of the pond on graph paper, choosing a suitable scale.



Pupils investigating the distribution of plants growing in mud at one end of a pond The girl on the bank is noting down results

BIRDWATCHING

This is a fascinating study which can become a life-long hobby.

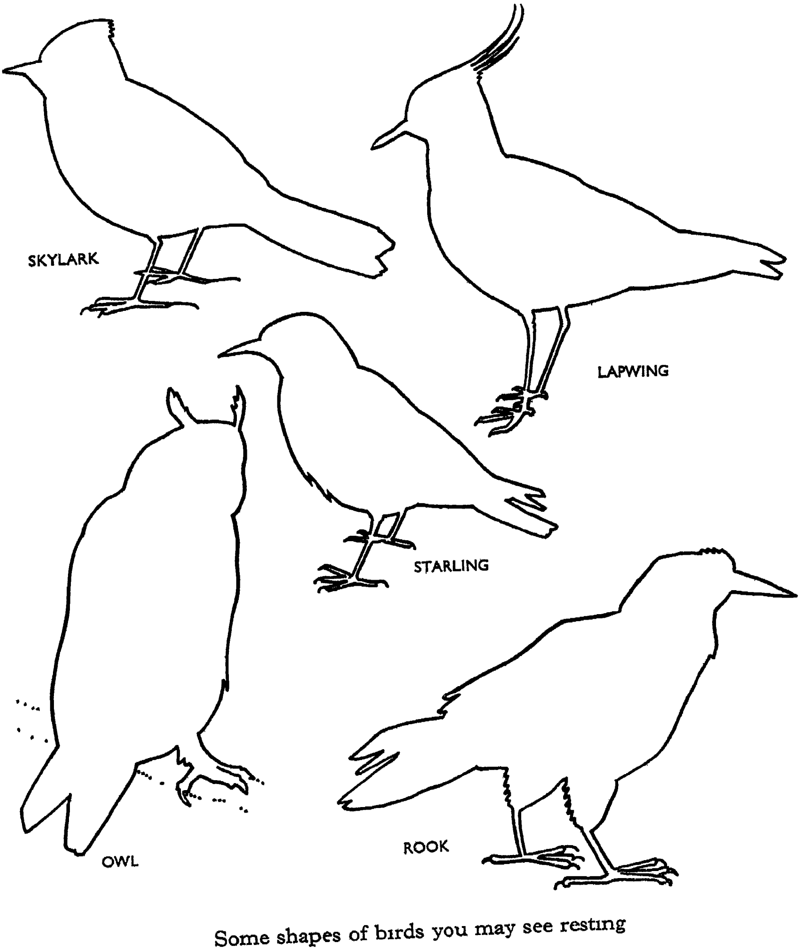
It requires very great patience and the ability to "freeze" (that is, to stand perfectly still) and to move silently—like a Red Indian. It is one of the best ways to learn to observe carefully. A small telescope or a pair of binoculars is useful but not essential. From the Appendix of Book I, you have already learned how to begin to study birds. You will be aware that they are of interest

to Man not only because some of them help to destroy insect pests but also because of their remarkable powers of flight, their instinctive abilities (such as nest building and migration) and the pleasure they give by their beautiful appearance, their interesting habits and their delightful song.

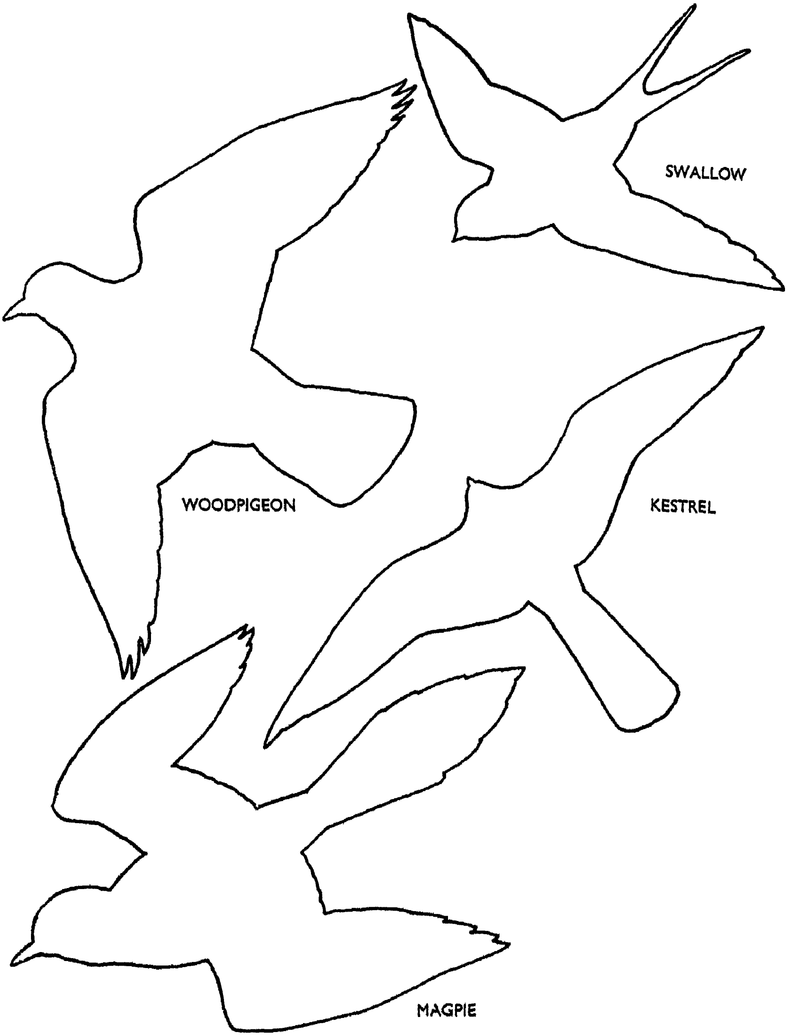
Some fifty kinds of birds are resident in this country throughout the year and more than one hundred and twenty others come either as summer or winter visitors. If you can get in touch with local members of the British Ornithologists Union, they may be able to tell you of projects undertaken in your area in connection with migration and other problems.

You will find that certain birds frequent certain habitats, for all birds are adapted to particular ways of living and feeding. We associate the Kingfisher with fresh water, and if we wish to study its habits, we visit a stream where fish are plentiful. We look for Lapwings on ploughed land and Curlews on the moors and other places where there are few human beings. Each kind of bird lives in the place where it can obtain the kind of food it needs and where it can nest in safety. It will cease to be common and may even become extinct if conditions change in its habitat so that its food becomes scarce or its enemies prevent it breeding. If you have the opportunity, do not fail to visit one of the bird sanctuaries, such as the Severn Wild Fowl Trust at Slimbridge, Gloucester, where you can observe many of the birds which are protected there.

Learn to distinguish between the various families of birds: between the birds which eat insects (with a delicate fine beak); those which eat grain (with a short powerful beak); and those which catch fish or tear flesh (with a strong curved beak). Learn to know which birds you



Some shapes of birds you may see resting



Some outlines of birds in flight

might expect to see in each of the following habitats: in gardens, in farmland, in woodlands, uplands, and moors, on the sea and along the shores, on rivers, lakes, rocky coasts and islands. Some birds nest or rest in one of these haunts and feed in another.

Go out in pairs. Take it in turn to be observer and recorder. Estimate the approximate size of each bird you wish to identify (compare its size with some bird you know well). Note the type of beak and any distinctive features of form or colour which may help to name the bird; its type of flight (whether light/heavy, rapid/slow, long/short, direct/dipping, sailing or gliding); its manner of movement on land; and any other noticeable behaviour.

THINGS TO NOTE ABOUT BIRDS

1 Make a monthly list of birds heard singing.

2 Keep a record of dates of arrival of migrants.

3. Keep a record of nesting dates without disturbing the birds too much Pay not more than one visit to the nest each day. Do not frighten the sitting bird and do not stay long

4 Record the date when the birds are seen building the nest: and

5. Dates of egg laying, hatching, and flight of young birds.

Some books to help you are:—

Life of the Robin by David Lack

The Observer's Book of Birds

Bird Watching for Beginners by Bruce Campbell

Fontana Bird Guide by R. S. R. Fitter and R. A. Richardson. (There is a useful key for identifying birds, at the back of the book.)

MORE THINGS TO DO

1. Carry out an experiment rather like one done by the great biologist Charles Darwin. When you come back from outdoor field work, scrape the mud from your shoes into a clean seed pan or dish. Water it well and cover with a square of glass. Leave the pan in a light, warm place and count the number of seedlings which grow from the mud. Later uncover the pan and put it out of doors, remembering to water it well. You may be able to recognise some of the plants dispersed by you in the mud on your shoes.

You may like to repeat the experiment carried out by another eminent botanist who collected seeds fron his trouser turn-ups, on his return from a country walk, and planted these seeds on top of a layer of clean boiled sand. Why do you think it is necessary to boil the sand?

2. Make an illustrated booklet on ways in which plants are pollinated. Watch carefully the plants you choose, noticing which insects visit the flowers, at what time of day, and how they carry out pollination. You will need to examine the flowers carefully and make drawings of flowers cut from bottom to top. (Hold the flower firmly between the thumb and first finger of your left hand: pass a sharp penknife up through the flower and you should find you can divide it into two equal parts.) Look for any wind-pollinated flowers and make observations on them. Is there any connection between the time of flowering or the habitat of the plant and wind pollination? Some flowers with most interesting pollination methods are Broom, Musk, Sweet Pea, Grasses and Wild Arum (a colony of small flowers in a pointed sheath). Dandelion is particularly interesting; for although there is an elaborate method to ensure pollination, it seems quite unnecessary as this plant has been found to produce seed without fertilization. Get as much information as you can by observation and consult books for further details.

Edward Step's *Wayside and Woodland Blossoms*, and many text-books of Botany will help you.

3. Repeat the observations on pollen and on insect visitors to flowers described on pages 182 and 183 in Book III.

4. Make a class exhibition to illustrate pollination of plants in one habitat. Include any references you can find about pollen, including such things as "Pollen and Hay Fever," "Fossil Pollen," "Shapes of Pollen Grains," "The Pollination of Apple Trees," etc.

5. Cut out a block of turf or a block of soil from any habitat. Bring it to the Science Room and place it in a seed box or dish. Keep it watered and observe the growth and development of the plants through several weeks. Watch for animals associated with the plants. Identify any you see and keep a record of their activities.

6. Collect fruits from a habitat and group them according to their method of seed dispersal. Display them for the rest of the school to see. Name them and add drawings and notes.

7. Note any plants in a habitat which seem to be affected by light of different strengths: for example, flowers which open only in bright light, or only at dusk; leaves which fold down in dull (or bright) light, etc. Watch the position of Runner Bean leaves in bright light and in dull light. Notice the angles between the leaves and the stem of Meadow Soft Grass (found in woods) growing in sun and in shade. Notice that the shoots of many plants bend towards light reaching them from one side.

8. Search a habitat for a tall and a short plant of the same kind. Measure each, and note exactly where it was found: for example, in full sun, in deep shade, in damp soil or dry soil (test the soil with your fingers to discover its type), in an exposed or sheltered position. Repeat with other kinds of plants. Can you now suggest why the plants are so different in size?

9. Find out, by counting, the number of seeds produced by the most common and by the rarest plants in a habitat. Carry out experiments with these seeds to find their percentage germination (Book III, pp. 176, 177). Note their method of seed dispersal.

10. Kill some green leaves by plunging them into boiling water for a few minutes. Remove and place in a tube of methylated spirit to dissolve out the chlorophyll. Divide the green solution into three

parts. To one, add a few drops of dilute acid. to another, add a few drops of alkali such as a very dilute solution of washing soda in water. Notice the colour change. Acids or alkalis are produced as waste products in some plants and, by autumn, may affect the colour of the leaves.

11. Pour the rest of the chlorophyll solution into a shallow dish and stand a piece of blackboard chalk upright in it. Watch the solution rising in the porous chalk. After an hour or so, look again and notice that the green colour has separated into bands of dark green, lighter green and yellow Chlorophyll is really a mixture of these pigments.

12. Use a rain gauge (Book II, p. 177) and a whirling hygrometer (Book II, p. 81), daily for a period of several weeks, to find rainfall and relative humidity of the air in a habitat.

SECTION 4

Making Use of Natural Sources of Energy

IN CHAPTER SEVEN of Book II we learned that the kinds of energy we need to help us in our work and to keep us comfortable are heat, light and mechanical energy. These may be obtained directly from some natural source of energy, but, more generally nowadays, the natural energy is converted into electrical energy which is distributed through cables to houses and factories and then converted back to heat, light and power as required.

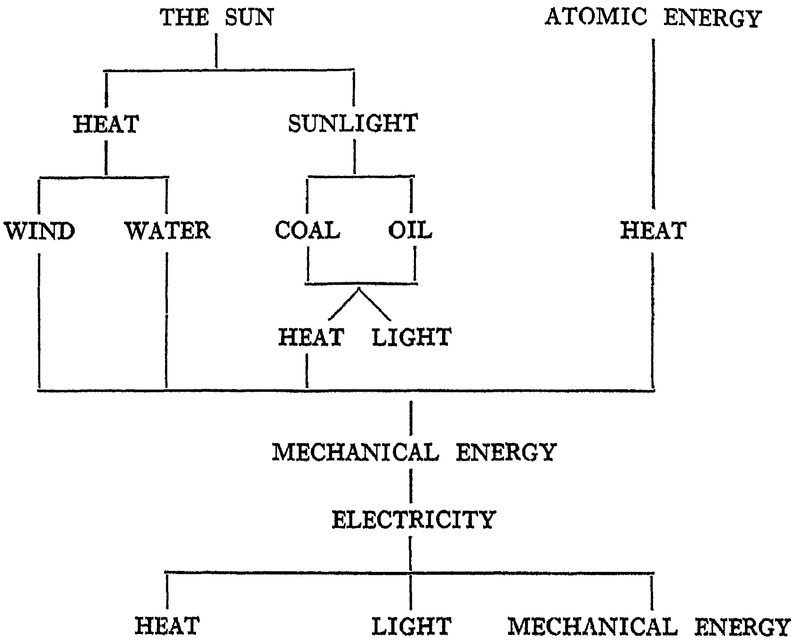
The most important natural source of energy is the sun. Life could not exist here if light and heat from it did not reach the Earth continuously. The winds and the water cycle on which water power depends, are both caused by the sun, and coal and oil possess chemical energy stored through the action of the light of the sun millions of years ago.

For thousands of years, apart from his own physical energy and that of animals which he domesticated, the energy of wind and water were the only forms which Man could use to do work for him. It was not until coal, and later, oil, were discovered and engines were invented which could use the chemical energy stored in coal and oil, that civilization as we know it today could begin to develop. The invention of the electrical generator or dynamo which converted mechanical into electrical energy made it possible to produce useful large quantities of

electrical energy, and, through the electricity, to get heat, ight and power wherever they were needed.

The latest form of natural energy to be harnessed by man is atomic energy.

The following diagram shows the relationship between the natural sources of energy, electricity and the forms of energy we need:—



In what follows we will concern ourselves with the production of mechanical energy, the uses of which fall under three main headings. They are: (1) to propel the various forms of transport—motor vehicles, trains, ships and aeroplanes, (2) to work industrial and domestic machinery, and (3) to produce electricity.

The two main forms of engine used in converting the

natural forms of energy into mechanical energy are piston engines and turbines. In the first of these a piston is made to move backwards and forwards along a cylinder by the expansion of steam or gases, and the movement of the piston is made to turn a wheel. In the turbine a wheel with fan-like blades is made to turn by flowing water or expanding steam or gas. Both types will be described more fully in the section on "Using the Energy of Coal and Oil."

USING THE ENERGY OF WIND AND FLOWING WATER

Wind Power

Wind energy has been used since the earliest times to propel sailing boats, and has probably been used for more than three thousand years to turn windmills on land. The earliest known windmill in England existed in the twelfth century.

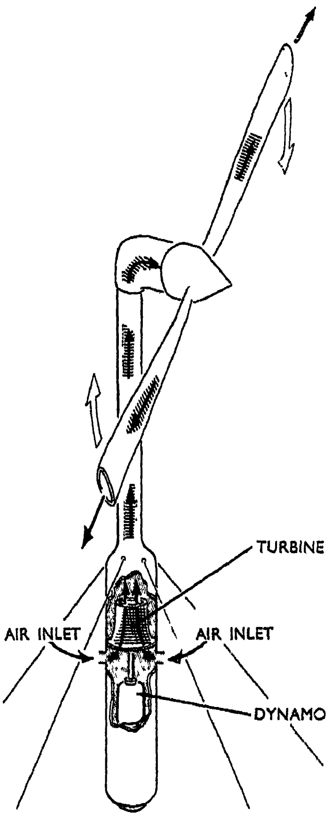
In England most of the picturesque windmills, which in the past ground corn or pumped water, have been out of use for many years, but in parts of the Continent they are still quite common.

A modern form of windmill which may frequently be seen in the British countryside consists of a propeller with many blades set at the top of a metal framework tower. It is usually employed to generate electricity for isolated homes and farms not connected to the main electricity supply, or to pump water.

In recent years research has been carried out in many countries on the problem of building large wind-driven generators (called aerogenerators) which will produce large quantities of electricity to be fed into the main supply system, and so save other fuels used in the generation of electricity. One American aerogenerator, worked

by a propeller with two blades each 66 ft. long, was designed to produce 1,250 kilowatts (1,250,000 watts) of electrical power.

A machine which is being tested in England consists of a hollow two-bladed propeller, 80 ft. across, at the top of a tube which acts as a mast. As the propeller rotates the air inside it is flung out of the openings at the tips by centrifugal force and is replaced by air drawn up through the hollow mast. The lower end of the mast contains a turbine (really a small and complicated windmill) which is turned by the draught. The turbine shaft is connected directly to the shaft of a generator, so that when the turbine rotates electricity is produced. The machine, in which the ideas of a French inventor J. Andreau are used, can produce 100 kilowatts of power.



Water Power

The waterwheel is at least as old as the windmill but it is still in use in many parts of the world, and many waterwheels are still doing useful work in Britain today.

The simplest type of waterwheel is a large paddle wheel, the lower blades of which dip into a channel of

flowing water. The water pushes the paddle and causes the wheel to turn. In another type of wheel, fast moving water from a narrow stream hits the top blade of the wheel, and the force of the water and its weight cause the wheel to turn. In the eighteenth century the largest waterwheels developed about 10 horse-power. To compare engines rated in horsepower (H.P.) with those rated in kilowatts it is convenient to take 1 H.P. as equal to $\frac{3}{4}$ kilowatt. (1 H.P. = $\frac{3}{4}$ kilowatt and 1 kilowatt = $1\frac{1}{3}$ H.P.)

Hydroelectric Schemes

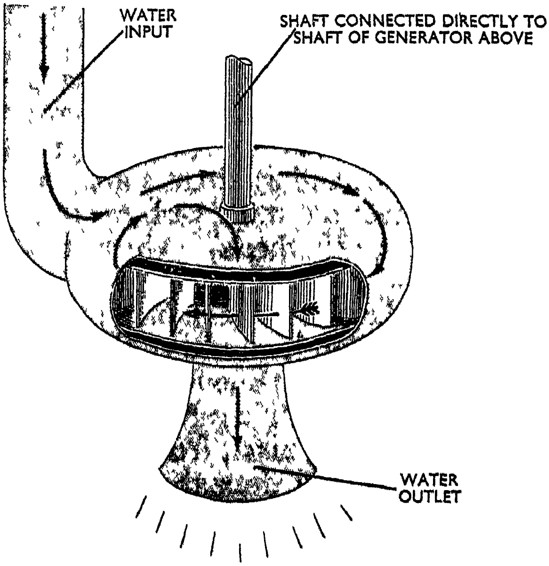
The modern development of water power is seen in the hydroelectric schemes which are found all over the world. In these water is allowed to fall in pipes, sometimes through great heights, and so attain a great speed. At the lower end of the pipes are water turbines (really specially designed efficient waterwheels), which turn electrical generators.

Hydroelectric schemes depend on having a constant supply of water at a high level and so the largest schemes are always found in mountainous country or associated with large waterfalls like Niagara. In the case of the Niagara scheme, water is taken from the main stream at the top of the falls, is led through pipes to the turbines which are on a level with the foot of the falls, and is then returned to the lower main stream.

In mountainous country a valley is dammed to give a large reservoir with a constant level of water. From this reservoir water is drawn off through pipes to turbines in a power station at a lower level. The greater the difference in height between reservoir and power station, the faster will be the movement of the water reaching the turbines and the greater will be the energy available from it.

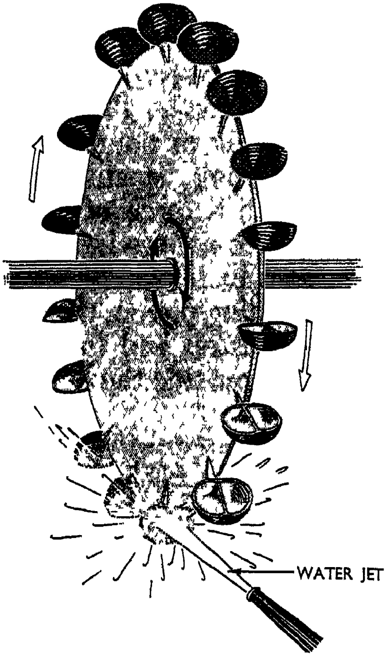
When the water is in the reservoir it is said to have *potential energy*—it could do work if it were allowed to. By the time it has reached the turbine its energy is energy of movement and is called *kinetic energy*. The kinetic energy of anything which is moving is proportional to the square of its velocity, so if the velocity is doubled, the energy is four times as great.

The heart of any scheme for turning water power into electrical power is the turbine. The diagram shows one of



a type called a reaction turbine with part of the casing cut away to show the paddle wheel inside. Other types of turbine used are the propeller type, which has a rotating part (rotor) like a ship's propeller and is used with low water pressure, and the Pelton wheel type which is used for high pressures of water. In the Pelton wheel high-

speed jets of water are directed at small cups (each with a central partition), which are attached round the rim of a wheel.



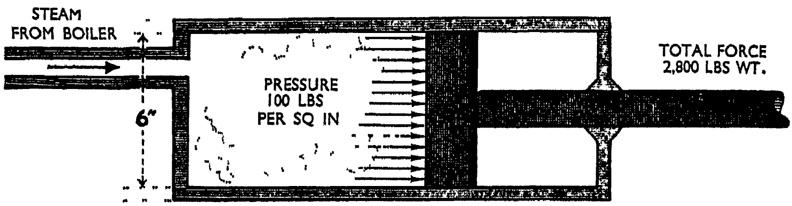
USING THE ENERGY OF COAL AND OIL

Heat can be obtained from coal by burning it, and both heat and light can be obtained from coal gas and from oil. The most important use of both coal and oil, however, is to produce mechanical energy for land, sea or air transport, and for the generation of electricity. Both fuels may be used in piston engines or in turbines.

Steam Energy

When water is heated it evaporates more rapidly, and if it is boiled the volume of steam produced is some 1,600 times as great as the volume of the water from which it came. If the steam is not allowed to take up this new volume it becomes compressed and exerts a pressure on the inside of the container. Pressure is measured as force per unit area, usually in pounds weight per square inch. A boiler containing steam at a pressure of 100 lbs./square inch has a force of 100 pounds weight pushing outwards on each square inch of its surface.

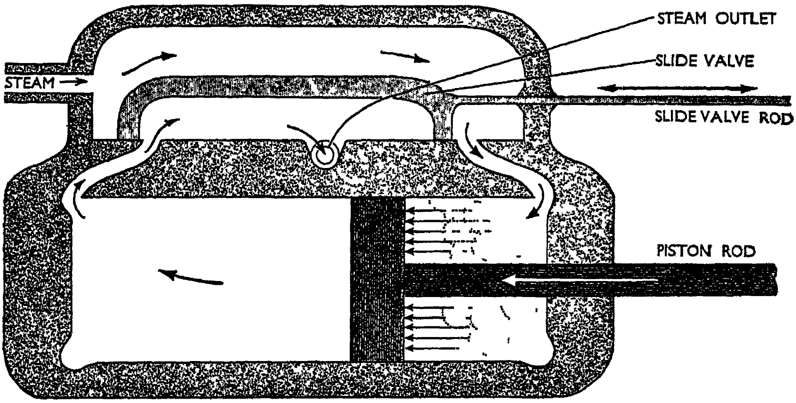
If steam from such a boiler is fed through a pipe to a cylinder containing a sliding piston, the same pressure will act on the end of the piston and force it to move. The piston can be connected outside the cylinder to a machine



and the total force which can be exerted on the machine will depend on the area of the piston. Each square inch of the piston has a force of 100 lbs. weight acting on it, so the total force will be the area of the piston in square inches $\times 100$ pounds weight. If the piston is 6 in. in diameter (about 28 square inches in area) the force will be $28 \times 100 = 2{,}800$ pounds weight. The bigger the area the bigger the force.

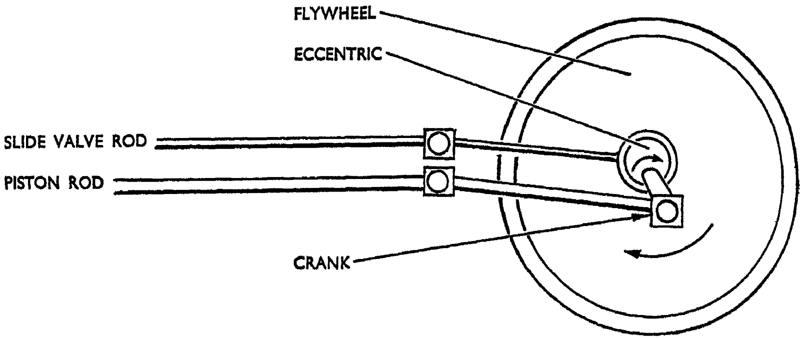
In our simple engine the piston would travel to the end of the cylinder and stay there. To be useful the movement

must be continuous and the piston must somehow be returned to the original position to start the cycle of movement again. One way of doing this would be to allow steam into the front end of the cylinder to push the piston back. This means that the steam supply to the back end of the cylinder must be cut off and the steam



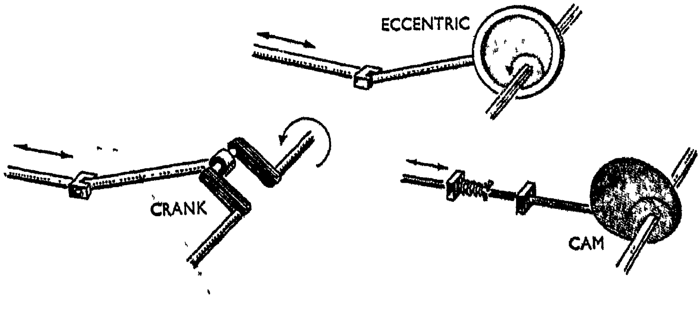
already in the cylinder must be allowed to escape. Then to move the piston forward again the steam supply to the front end would have to be cut off, the steam in the front end would have to be allowed to escape and steam would have to be supplied again to the back end. A slide valve system which would enable us to make a piston go backwards and forwards like this is shown in the diagram above.

Although we have arranged that the piston can be kept moving, this backward and forward motion, which is called *reciprocating* motion, is of little general use. What makes the piston engine really useful to us is that the reciprocating motion can be changed into continuous



turning or rotary motion by means of a crank and a flywheel. The flywheel smooths out the motion of the engine. Once we have rotary motion we can turn the wheels of a railway engine or turn a dynamo to produce electricity.

Together these diagrams show how a simple engine works. Notice that the valve system is being operated from the axle which is being turned by the piston. The problem of operating the valve gear is the opposite of getting rotary from reciprocating motion. The valve gear must have a reciprocating motion and it must be obtained from the rotary motion of the flywheel shaft. This can be done in three ways, by a crank, by an eccentric or by a



cam. The three methods are shown in the drawing at the foot of the previous page, but the method shown in our diagram of the steam engine is the eccentric.

Steam Turbines

The steam engine seems a very clumsy way of turning the chemical energy of coal or oil into rotary motion. The fuel has to be burned to produce heat which turns the water in the boiler into steam. The steam pressure has to cause pistons and valve gear to move to and fro before the rotary motion required is obtained. The efficiency with which the heat energy of the fuel is turned into the energy of expanding steam depends on the design of the boiler. An ordinary cylindrical boiler like a large oil drum would be very wasteful, because most of the heat would pass round it and be lost. If the boiler had several tubes through it so that the hot gases from the burning fuel could pass right through the middle of the water, the heating would be much more efficient. The boilers of steam locomotives are like this. In modern steam generating plants the water is heated in pipes which are so arranged that they pick up most of the heat from the fuel, and the tanks which look like boilers are simply for storage of water and steam.

Having obtained the steam energy as efficiently as possible, the next stage is to convert it into rotary motion efficiently. The friction and inertia in the complex moving parts of a piston engine must waste a lot of energy and if the steam, instead of pushing a piston, were made to produce rotary motion directly we would expect the wastage to be much smaller. If the expanding steam were passed along a pipe in which there was a propeller or a small set of windmill vanes, these would be made to

rotate. This is in fact the principle of all turbines. We are thus using windmills (and waterwheels in water turbines), the oldest methods of harnessing natural energy, in a new and far more efficient manner. We make an artificial wind of expanding steam which is channelled through a pipe to a turbine where it expends the maximum possible amount of its energy in making the rotor turn.

A single propeller or fan in the pipe would not be efficient because it would be moved by only a small part of the energy of the steam and so in steam turbines there are many sets of fan blades close to each other on the same shaft. Between each pair of rotating fans there is a set of fixed blades which prevents the steam from rotating bodily with the fans. As the steam passes through the turbine and loses energy the size of the fan is increased to make full use of the decreasing energy. The rotor of a turbine may be geared to turn the propeller of a ship or to turn the wheels of a locomotive or any other machinery, or it may be connected directly to a dynamo to produce electricity.

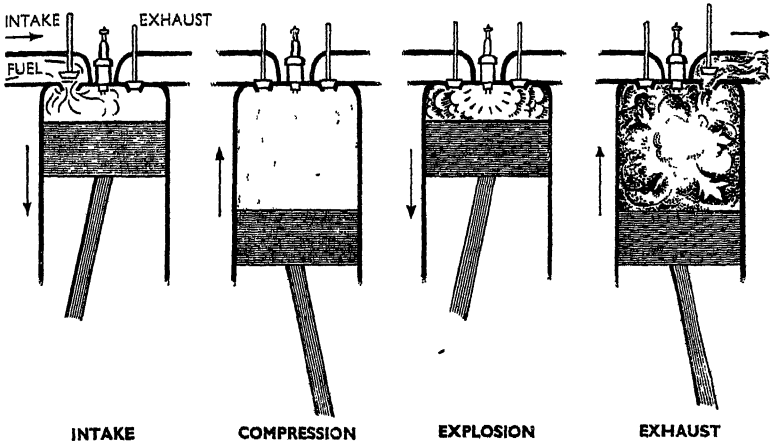
In a modern steam turbine as much as 85 per cent of the original steam energy may be converted into mechanical energy.

ENERGY FROM PETROLEUM AND FUEL OIL

Oil may be used to supply heat for steam engines, but it is also used to produce mechanical energy more directly in engines which depend on the expansion of exploding petrol or fuel oil. The fuel burns inside these engines and so they are called internal combustion (or IC) engines. There are two types of IC piston engines: the petrol type and the Diesel type.

The Internal Combustion Petrol Engine

In this engine a compressed mixture of petrol vapour and air is exploded inside a cylinder by means of a spark and the expansion caused forces a piston to move. The complications of the engine are due to the need for accurate timing of the spark, for expelling used gases and taking in and compressing a fresh mixture, and to the



need for using the correct mixture of petrol vapour and air.

The best way of understanding the timing of piston, valves and spark is to follow the changes which occur in a single cylinder as it goes through one complete cycle of operations. The four-stroke engine is described as it is most commonly used.

The four sections of our diagram show the four parts of the cycle. Each picture shows only the cylinder, piston, spark plug and valves. In the first picture the piston is beginning to move downwards and is drawing in fresh mixture through the open intake valve. In the second

picture the intake valve has closed and the piston is moving up and compressing the mixture in the cylinder. In the third picture the compressed gases have been ignited by a spark and the resulting expansion is forcing the piston down again, and in the fourth picture the piston on its next up stroke is forcing the used gases through the open exhaust valve.

The reciprocating motion of the piston is turned into rotary motion by means of a crank as in the steam engine. A single cylinder would have to get enough energy from the firing or explosion stroke to take it through the other three strokes of exhaust, intake and compression before the next explosion could supply more energy. This can be overcome by using a flywheel which stores the energy of the firing stroke and feeds it back to the engine during the other three strokes. The energy it needs to feed back is less than the energy received during the firing stroke so there is surplus energy to do work if the engine is connected to a machine.

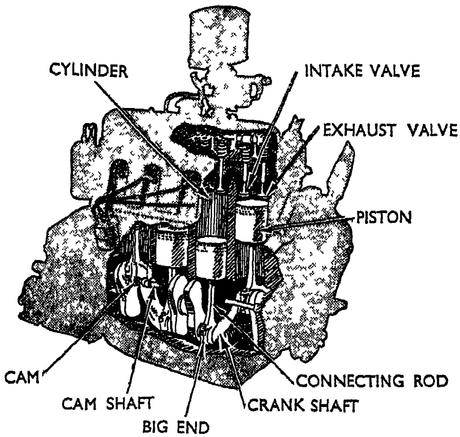
A single cylinder gives only one impulse to the crankshaft in two revolutions. By using two cylinders working on the same shaft and firing alternately, one impulse can be given to the shaft each revolution, and by using four cylinders working the same crankshaft two impulses may be given each revolution. Engines are made with large numbers of cylinders. Generally speaking, the greater the number of cylinders the more powerful and the smoother running is the engine, because there are more impulses to one revolution of the crankshaft.

The diagram below is a simplified picture of a four cylinder four-stroke engine of the type commonly used in motor vehicles.

The bigger the number of cylinders the more complicated becomes the valve and spark timing. Valves are

usually operated by a shaft which is driven by the main crankshaft and so each valve always opens and shuts at the same position of the crankshaft, no matter how fast it is turning. If the valves are adjusted to be correct when the engine is turned by hand, they should be correct when it is running at speed.

Timing of the spark is carried out by means of a

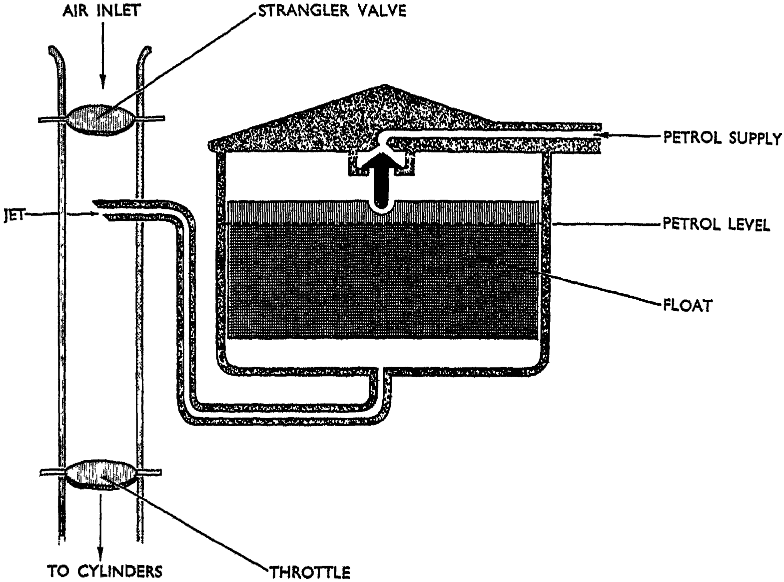


distributor which is also geared to the main crankshaft. The distributor supplies a high voltage of electricity to each spark-plug in turn, the plug supplied at any one time belonging to a cylinder which has just completed the compression stroke. Distributors can be rotated so as to advance the firing or retard it. To advance the firing means to cause the spark to occur earlier in the cycle, and to retard the firing means to cause the spark to occur later.

The Carburetter

The supply of vapour and air to the cylinders is regulated by the carburetter. The carburetter consists of

a float chamber, into which is pumped petrol from the tank and which is connected to a jet placed in a pipe through which all the air entering the cylinders of the engine is drawn. The float in the float chamber closes a valve which prevents any more petrol being pumped in



when the petrol in the carburetter reaches the level required for the jet to function correctly. The float and valve control the flow of petrol into the carburetter in the same way that the ballcock and valve control the flow of water into a water storage cistern.

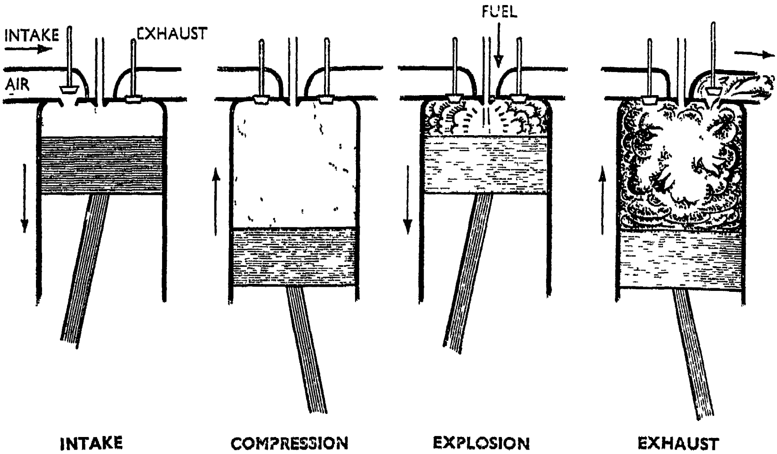
The air being drawn into the cylinders passes the jet in the intake pipe at a high speed; takes liquid petrol from it and breaks the liquid up into a fine spray before the mixture reaches the cylinders. When an engine is cold

the spray is drawn into the cylinder and if some of it collects on the spark-plug points the firing spark does not occur. The engine will not start and may have to be left for some time until the liquid petrol evaporates. When the engine is hot this does not happen, as any spray which is drawn in and touches the spark-plug is immediately evaporated.

In the intake pipe are two butterfly valves, one on each side of the carburetter jet. The one between the jet and the air is called the *strangler valve* and controls the amount of air entering the intake tube, and the other, called the *throttle valve*, controls the amount of mixture entering the cylinders. In a car the throttle is connected to the accelerator pedal which is used to control the speed and power of the engine, and the strangler valve is connected to the choke which is used only when a mixture rich in petrol is needed for starting. The diagram shows a very simple form of carburetter—most practical carburetters are much more complicated.

The Diesel Engine

In this type of engine no spark-plug is used. When a gas is compressed it gets hot. If you pump up a cycle tyre energetically the end of the pump may become too hot to hold. You are compressing air which becomes hot inside the pump and the heat which is transferred through the wall of the pump may be sufficient to burn your hand. If the compression is great enough, the temperature might become sufficient to cause an easily inflammable gas to burst into flame. This idea is used in the Diesel engine. As the burning of the fuel is caused by the heat of compression in engines of this type, they are also called compression ignition engines.



The diagram shows the four stages in the operation of a single cylinder in a four-stroke Diesel engine. In the first picture the piston is moving down and drawing air in through the open inlet valve, and in the second picture the inlet valve has closed and the air is being compressed by the piston moving upwards. At the end of the compression stroke (third picture) a small amount of hot oil is forced into the hot compressed air in the cylinder, it ignites and the expanding gases force the piston down. In the fourth stroke, shown in the fourth picture, the exhaust valve opens and the used gases are forced out by the rising piston. The exhaust gases are used to heat the oil before it is injected into the cylinders.

As in the four-stroke petrol engine, only one impulse is given to the crankshaft every two revolutions. This can be overcome, as before, by making a single cylinder engine rotate a suitable flywheel or, as is more usual, by having several cylinders rotating the same crankshaft but firing at different times. With Diesel or petrol engines,

however many cylinders there are, flywheels are still used to smooth out the motion.

A compression ignition engine may be designed to run on any of a large range of fuel oils, from heavy crude oil to the light fuel oils, or it may be designed to run on a gas. The gas used is often a by-product of some industry, for example blast furnace gas, or it may be a gas like sewer gas which would otherwise go to waste.

Cooling Petrol and Diesel Engines.—The burning or explosion of gases in these engines causes a large amount of heat to be produced, and friction in the moving parts causes more. If the heat cannot escape, the temperature of the engine will rise and may become high enough to melt the metal of a moving part and cause the engine to *seize*. To prevent this, engines are either air-cooled or water-cooled. Air-cooled engines rely on the cooling effect of a draught of air past the cylinders. If the outside of the cylinder were smooth the air would be unable to take away sufficient heat, so the outside surface is made with deep fins on it which have the effect of increasing the area in contact with the air. More heat is transferred to the passing air and the engine does not rise above its correct working temperature. Air cooling is generally used only in low power engines but is also used in some powerful aircraft engines where the speed of the air past the cylinders, and the coolness of the air due to altitude, make the method effective.

In water-cooled engines the cylinder block is enclosed in a water jacket which is connected to a *radiator*. The top of the water jacket is connected by a pipe to a tank at the top of the radiator, and the bottom of the water jacket is connected to a tank at the bottom of the radiator. The radiator itself consists essentially of a large number

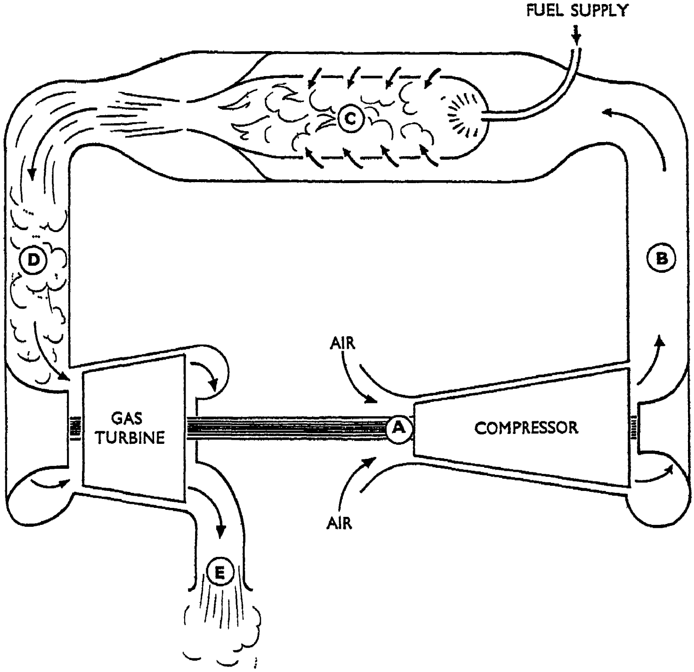
of thin walled tubes connecting the top and bottom tanks. When the engine and water jacket become warm, cold water from the radiator displaces the warm lighter water in the jacket and makes it flow up to the tank at the top of the radiator. The warm water begins to cool, and cools still further as it passes down through the thin walled radiator tubes. The water in the radiator is always colder than the water in the engine and therefore continues to displace it. A convection circulation is set up. For the radiator cooling to be effective, a draught of air must pass through it and this is obtained in motor vehicles by the movement of the vehicle and by a fan which is worked by the engine.

Sometimes a circulating pump is used to assist the natural circulation of the water, and in some special types of engine liquids other than water are used in the cooling system.

Gas Turbines

The energy of expansion of burning gases may be used to turn a turbine. The principle is simple but the difficulties of obtaining a continuous supply of expanding gas with sufficient energy to be useful, and of obtaining materials which will withstand the very high temperatures existing in gas turbines, are great.

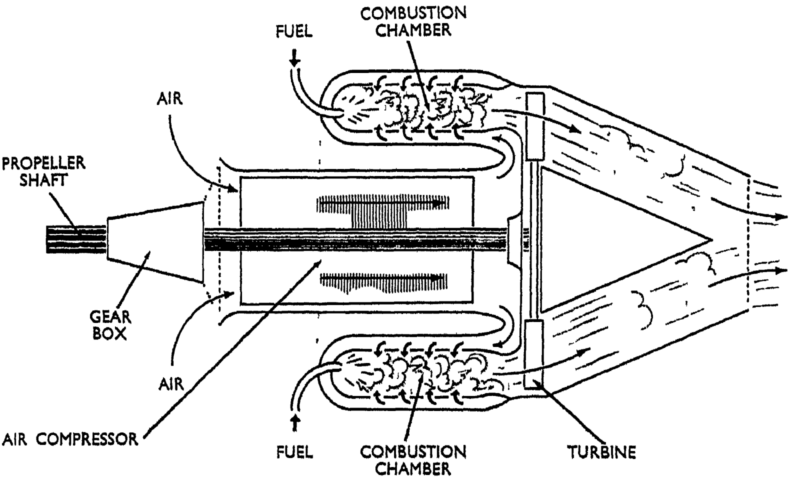
If you were to direct the flame of a painter's blow-lamp at a small windmill made of metal the windmill would rotate. If you held the lamp steady with the flame touching the vanes of the mill the speed of rotation would increase and the vanes would get hotter and hotter. They would get red-hot and might even melt if the temperature have high enough. This is the sort of treatment that a firingırbine has to undergo.



Our picture shows the general arrangement of a stationary engine of the gas turbine type. To start it, the shaft carrying the gas turbine and the compressor is turned by an auxiliary engine. Air is drawn in at A, compressed and sent up the right-hand trunking B, to the combustion chamber C. It then passes down D, past the turbine and out through the exhaust E. Once compressed air is circulating, oil fuel is supplied continuously to the combustion chamber, and the mixture of compressed air and fuel is ignited with a spark. The burning mixture expands rapidly and the expanding gases are forced at high speed through the open end of the combustion chamber, down the trunking D, through the

turbine, where they expend their energy in causing rotation, and finally the used gases are expelled from the exhaust E. Once this stage has been reached the auxiliary engine is no longer needed and the gas turbine will keep running under its own power so long as the fuel mixture keeps burning in the combustion chamber.

The turbine produces far more energy than is needed by the compressor, and the surplus energy can be usefully employed by gearing the shaft to machinery, or in the production of electricity.



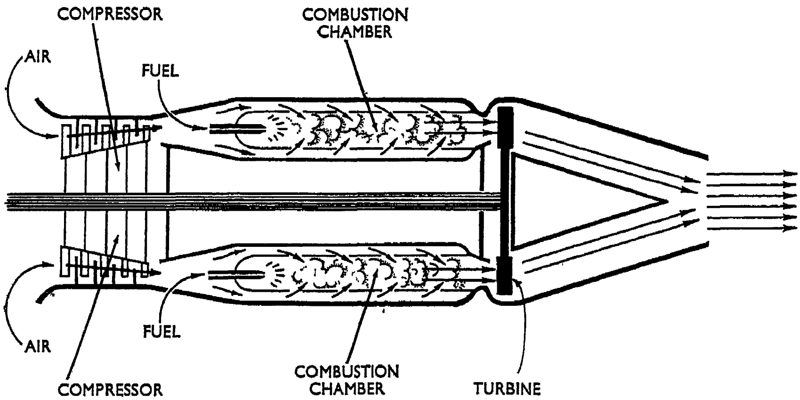
Gas engines of this type, in a modified and very much more compact form, are used in modern aircraft. They are called *turbo-prop* engines because a gas turbine is used to turn the propeller. The diagram above shows in a very much simplified manner the layout of a turbo-prop engine. There are a number of small combustion chambers arranged radially round the turbine shaft and the expanding gases from all the chambers act on the turbine at the

same time, thus producing a high power. The diagram, which is a cross-section, shows only two of the combustion chambers. The high speed of the turbine shaft is reduced, by a gear box at the air intake end of the engine, to the speed of rotation required by the propeller.

The exhaust gases, which still have a considerable amount of energy after passing the turbine blades, are passed straight out at the back of the engine and the thrust they exert assists the pull of the propeller.

Jet Engines

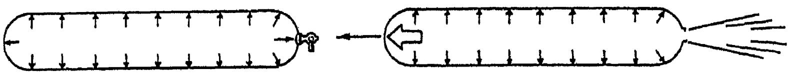
The aircraft jet engine functions in the same way as the turbo-prop engine we have just described. The main differences are that in the jet engine the turbine is used only to move the compressor, and that the motive power



is the thrust on the engine caused by the very hot, expanding gases being forced through a nozzle at the rear of the engine. The energy of the expanding gases is converted directly into the energy of movement of the engine through the air.

To understand how a jet engine is caused to move, let us consider the pressures exerted on a gas cylinder by a gas contained at high pressure inside it. When no gas is escaping from the cylinder (diagram (*a*)) the pressure will be exerting the same force outwards on every square inch of the inner surface. The force on each square inch has an exactly equal force acting in the opposite direction on a square inch of the far side of the cylinder, and the force on one end of the cylinder is exactly equal and opposite to the force on the other. All the forces are balanced so there is nothing to make the cylinder move.

Suppose now that the valve at the end of the cylinder is knocked off leaving a large hole there (diagram (*b*)). What are the forces acting now. We can see that all the forces on the inner sides of the cylinder are still balanced by opposing forces, but that the force acting at the closed end has no force acting in the opposite direction at the



(a) (b)

other end. The force on the closed end pushes the cylinder along, closed end first. This sometimes really does happen if the valves of high pressure gas cylinders are turned on full or are accidentally broken. Notice that the cylinder moves because the gas pressure *inside* pushes it and not because the gas coming out pushes against the air outside. The air outside is quite unnecessary, in fact the cylinder would move more easily if there were no air outside it at all.

If you imagine each of the combustion chambers of the jet engine as small cylinders of compressed gas with an

opening at one end, you will see that the engine is pushed forward by the pressure of the gases inside it, and not by the thrust of the escaping gases on the air behind. A jet engine does not need air round it in order to be able to move but it does need air to supply oxygen to burn the fuel in its combustion chambers. So the height to which jet aircraft can fly is ultimately limited to the height at which the jet engine can get just enough oxygen to burn its fuel.

Rockets

The motion of rockets is caused in the same way as that of jet engines. Gases are burned in a combustion chamber, and the resulting expansion builds up a high pressure. If one end of the combustion chamber is open, the pressure forces the rocket to move in the direction of the other end. The rocket moves for the same reason as the cylinder in diagram (*b*) on page 140, but the case of the rocket is lighter, so that the force of the compressed gases is sufficient to make it travel upwards against the pull of gravity.

The main difference between rockets and jet engines is that the chemical fuels used in rockets contain the oxygen necessary for burning. Thus rockets with a solid fuel, which is a mixture of saltpetre (potassium nitrate), carbon and sulphur, use the oxygen contained in the saltpetre for the burning of the carbon and sulphur, and rockets using liquid fuels carry liquid oxygen for the burning of the fuel. Some of the V2 war rockets used by the Germans were 46 ft. long and 5 ft. in diameter and weighed 12 tons, yet the alcohol and liquid oxygen fuel they carried sent them to a height of 60 miles, and they could fly 200 miles at a speed greater than that of sound.

A rocket carrying its own oxygen is not limited to travel in the atmosphere of the earth, but will travel even better in space where there is nothing to resist its movement. The space ship propelled by rocket motor and steered by subsidiary rocket motors is quite a possibility, but the difficulty is to get such a ship out into space with live human beings still on board to control it. A manned rocket starting from the earth for a journey, say, to the moon and back would have to start with all the fuel necessary for the complete journey. Although the rocket would probably coast for most of the distance the amount of fuel needed for acceleration at the start of each journey and for slowing down and safe landing at the end of each journey would be very great. Even if ships were built big enough to carry the necessary fuel there is still another difficulty to overcome. To escape completely from the earth's gravitational pull in order to be able to travel to the moon or to another planet, the ship would have to attain a speed of something like 25,000 miles per hour. At present such journeys are not possible, but no doubt the difficulties will be overcome and it is possible that you will see the beginning of space travel in your lifetime.

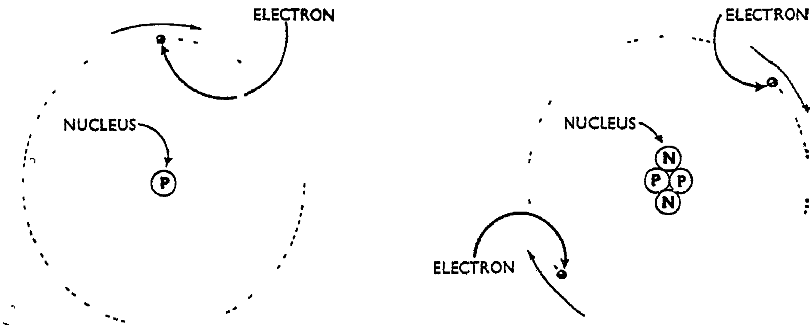
ATOMIC ENERGY

In Chapter I of Book III you learned that the numerous substances known to man are made up of various combinations of the atoms of chemical elements. There are only about one hundred chemical elements and of these few are found in any quantity.

All atoms are built up by different combinations of only three smaller particles called protons, neutrons and electrons. Electrons have a *negative* electrical charge and are so small and light that for practical purposes they may

be considered to be weightless. Protons have a *positive* charge equal in size to the negative charge of an electron, and neutrons have no charge. (They are *neutral.*) Both protons and neutrons have the same weight. The weight of an electron is actually about $\frac{1}{1800}$th of the weight of a proton or neutron.

Every atom has a heavy central part, called the nucleus, made up of protons and neutrons, with a number of



HYDROGEN ATOM HELIUM ATOM

electrons revolving round it, rather like planets revolving round the sun.

The simplest atom, that of hydrogen, has one proton for a nucleus and one electron revolving round it. The next simplest atom is that of the airship gas, helium. This has two protons and two neutrons in the nucleus, and two electrons outside it. Atoms always have an equal number of protons and electrons, so that they are electrically neutral.

As atoms become heavier so they become more complicated. For instance, the atom of iron has in it 26 protons, 30 neutrons and 26 electrons. One of the heaviest atoms,

that of uranium, has 92 protons and 146 neutrons in its nucleus, and 92 electrons revolving round it.

Isotopes.—The chemical behaviour of an element depends on the number of electrons possessed by its atoms. Any atom with 26 electrons is always iron whether it has the 30 neutrons stated above or not. Chemistry tells us nothing about the number of protons and neutrons in the nucleus.

Physical methods have been used to show that nearly all elements possess more than one weight of atom. An element may consist of atoms containing different numbers of neutrons.

For instance, uranium has several different types of atom, the commonest of which is the one mentioned above, which has 92 protons and 146 neutrons in its nucleus. The total number of particles in the nucleus is $92 + 146 = 238$, and this is the atom of what is called uranium 238. Another type of atom has the same number of protons but only 143 neutrons in the nucleus, this is the atom of uranium 235. Uranium 238 and uranium 235 are the same chemically, but their atoms differ in weight. Substances like these which have the same chemical properties but different numbers of neutrons in their nucleus are called *isotopes*. It is possible for one isotope of an element to change into another isotope simply by losing neutrons.

With uranium something more than this happens. The uranium nucleus is large and complex and it is unstable. At some time in its life it will explode, throwing out two neutrons and two protons. The loss of two neutrons would not alter it chemically but the loss of two protons completely alters the nature of the atom. It becomes an atom of a different element called thorium.

Elements which possess atoms which break up naturally

like this are said to be radioactive. A number of the heavier elements are radioactive.

The particles shot from the nucleus of the uranium possess great energy, but it is only a fraction of the energy locked away in the atom.

Men have learned how to split the atom of uranium 235 into two halves, three neutrons flying off by themselves in the process. The halves fly apart with colossal energy and it is energy of this nature which gives the almost unbelievable destructive power of the atomic bomb. Another chemical which gives a vast amount of energy in the same way is plutonium, which can be produced from uranium 238.

The first uses of this great new source of energy were warlike and destructive but it is now being harnessed for useful peacetime purposes. The most important peacetime use of atomic energy lies in the production of electricity. At present there is no direct way of using atomic energy. But we can use the heat obtained from slowing down the rapidly moving particles obtained in the atomic split up (the correct term is atomic fission). Heat obtained from atomic fission is used to heat water and so produce steam to run a turbo-generator.

At Calder Hall in Cumberland, the first atomic power station in Great Britain, heat generated by atomic fission is carried, by carbon dioxide gas which circulates under high pressure, to four towers in which there are complicated arrangements of water pipes. The gas heats the water, and produces steam, which is used to turn a turbo-generator and so produce electricity.

One ton of uranium in an atomic power plant could produce more electricity than is used by the whole of Britain in a month, a quantity of electricity that takes nearly 2,000,000 tons of coal to produce.

The main difficulty with atomic energy is that when the atoms split they emit a radiation which is harmful to human beings and so the region where atomic break-up takes place (the reactor) has to have a massive concrete shield round it 5 to 10 ft. thick. This heavy shield, weighing many tons, rules out at present the use of atomic energy for road, rail and air transport, but would be no great handicap for a large ship like the *Queen Elizabeth*. Such a ship has to have storage space for thousands of tons of fuel, whereas a small fraction of a ton of atomic fuel would take it round the world. Even with a very heavy reactor shield, the ship would gain considerably in carrying capacity.

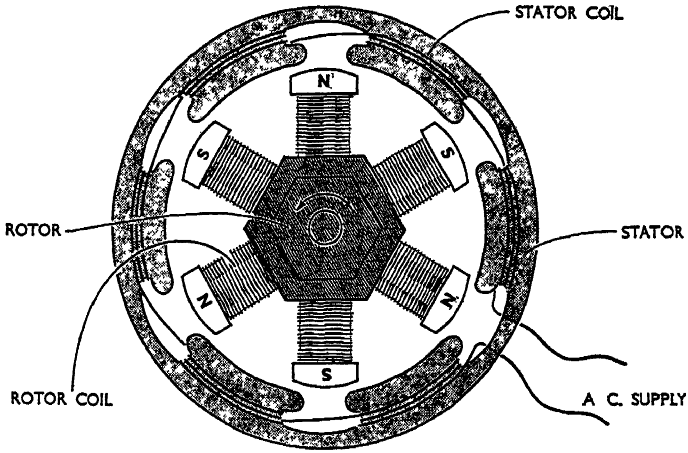
THE PRODUCTION OF ELECTRICAL POWER

You have seen that all the natural sources of energy are used to produce electricity, either by driving a turbine and generator directly as in the use of wind and water power, or by producing steam to drive a turbine. Petrol and oil engines are used mainly in transport but may be used to drive a generator in small power plants.

The rotary motion of the turbine is particularly suitable for driving generators. Alternating current (AC) is usually produced, and the machines producing it are called generators, dynamos or alternators.

In all dynamos there are two parts, the fixed part called the stator and the rotating part called the rotor, which usually rotates inside the shell formed by the stator. Both parts carry a complicated system of coils which generate the electricity. In Chapter 10 of Book III you learned how a bicycle dynamo works and that big dynamos producing AC are no different in principle. In

a big dynamo, to take the place of the permanent magnet in the bicycle dynamo, the rotor coils are connected to a direct current supply of electricity, so that each pair on opposite sides of the shaft acts as an electromagnet. The



DC is obtained from a small auxiliary generator. The diagram above is a very much simplified sketch of the cross-section of a dynamo which is more complicated than the bicycle dynamo. Dynamos used in the generation of electricity for the mains are very much more complicated than this.

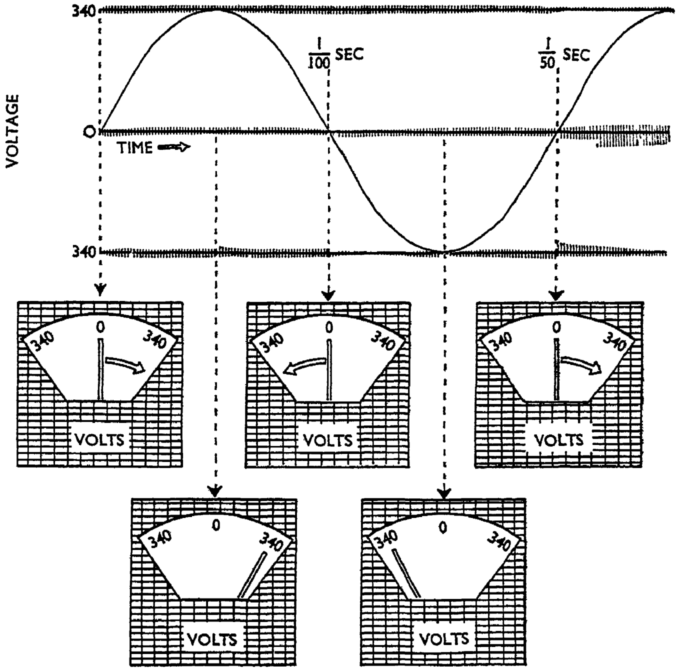
Alternating Current. AC mains electricity is conducted into a house through two cables, one of them called the *neutral* because its voltage is zero or very near to it, and the other called the *line* which transmits an alternating voltage. In electric plugs and switches, and on electrical apparatus, you will see the letters N and L next to two of the wiring terminals. The neutral wire should be connected to the N terminal and the line wire to the L terminal.

Suppose your house main is a 240 volt AC main. If you could connect a voltmeter with 0 in the middle of the scale to the two wires from the main, and then cause the alternations of the electricity to slow down so that you could watch the movements of the pointer on the meter, you would see that the voltage is continually changing. The voltage increases to a maximum of about 340 volts in one direction on the meter, then decreases to zero, then increases to 340 volts in the opposite direction and again decreases to zero (*see* diagram on page 149). This cycle of events keeps repeating.

In practice, the whole cycle of events takes only $\frac{1}{50}$th of a second so the meter you have used could not possibly follow it, nevertheless there are instruments called oscilloscopes which will follow the changes and make it possible to see what is happening.

You will notice that, although it is called a 240 volt main, in practice the voltage between the two cables is varying continuously between 0 and 340 volts. The reason is that the heating effect produced by this AC main when it is connected to, say, an electric fire element is the same as the heating effect which would be obtained if the same element were connected to a 240 volt DC supply. An AC supply is said to be 240 volts AC when it produces energy at the same rate as a 240 volt DC supply.

In the house supply there is only one alternating voltage. Such a supply is called a single-phase supply. The alternators which produce electricity in our generating stations have three separate line cables coming from them, each carrying an alternating voltage, but with the alternations out of step. In each cable there are 50 alternations per second but the alternations in any one cable are out of step by $\frac{1}{3}$ of $\frac{1}{50}$th of a second with the alternations



in the other two cables. A three cable supply is called a three-phase supply.

You will probably find that the power points in your house are connected to the fuse box by three wires, and that you use three-pin plugs on your electric fires and other apparatus. This has nothing to do with three-phase electricity. The third wire is simply an earthing wire which makes the apparatus safe if a fault should occur in it.

A three-phase supply functions in the same way as a single-phase supply but the apparatus involved is more complicated. In what follows we will think in terms of a

single-phase supply but you must remember that for most power distribution a three-phase supply is in fact used.

The Distribution of Electricity

AC is so important because a supply at one voltage can be easily converted to a supply at another voltage.

If we wish to change a 12 volt DC supply to, say, a 240 volt DC supply, we can do so by using the 12 volt supply to run a motor which turns a generator producing the 240 volt supply. Such an arrangement is costly, clumsy and liable to breakdown because of the constantly moving parts.

With AC there is a much more simple method.

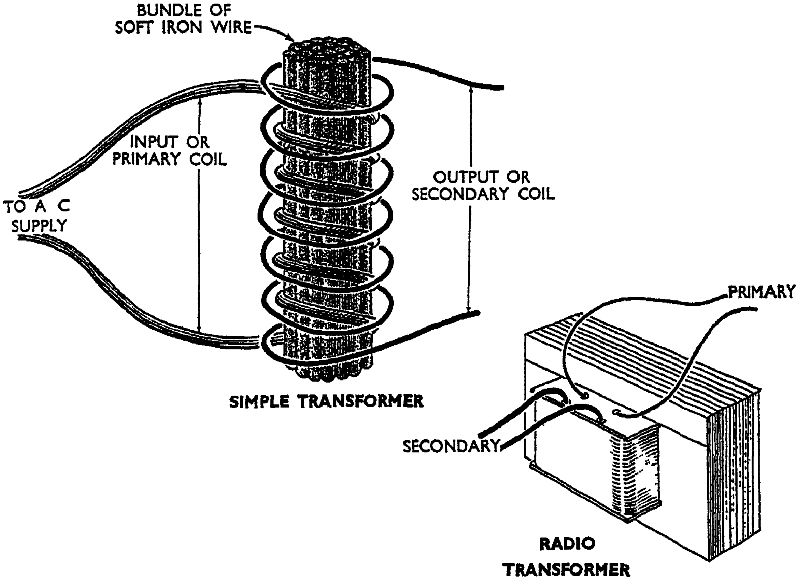
If direct current is passed through a coil of wire the coil acts like a magnet, but if an alternating current is passed, the coil acts like a magnet whose poles are changing places 100 times a second. An alternating magnetic field is created. A second coil of wire anywhere in this changing magnetic field will be affected by it and will have an alternating voltage produced (induced) in it. The voltage depends on how closely the coils are linked and the number of turns of wire they have in them.

To get as much energy as possible from one coil to the other they are wound one on top of the other on a core of soft iron. A device like this for changing an AC supply of one voltage into an AC supply of another voltage is called a *transformer*. The relationship between the voltages in the two coils is

$$\frac{\text{voltage in output coil}}{\text{voltage in input coil}} = \frac{\text{number of turns in output coil}}{\text{number of turns in input coil}}$$

The input coil is also called the *primary* coil and the output coil the *secondary* coil.

In radio mains transformers more than one secondary coil is found. One of the secondaries will have many times the turns of the primary coil and will produce the voltage



higher than mains voltage which is required by the valves. The other secondaries (there may be several of these) have only a few turns and may produce supplies of 2, 4 or 6·3 volts for panel lights and valve filaments.

To produce a 4 volt supply from a 240 volt main supply the ratio

$$\frac{\text{number of turns on the secondary coil}}{\text{number of turns on the primary coil}} \quad \text{would equal } \frac{4}{240} = \frac{1}{60}.$$

The secondary coil of the transformer would have one sixtieth of the number of turns on the primary coil.

A transformer has no moving parts and, providing it has adequate insulation and has wires large enough to carry the currents required in safety without overheating, there is nothing which can go wrong with it.

In the distribution of electrical power, transformers are used to turn the electricity generated at the power stations into electricity at a very high voltage. The supply may then be transmitted over great distances, usually through overhead cables, and then transformed down again to the lower voltages required in use.

The reason for the high voltage transmission is that the cables required to carry the currents are much thinner than those required to transmit the same power at low voltage.

For example, suppose we wish to transmit a power of 1,000 kilowatts (1,000,000 watts). If the voltage of the supply is 250, the current necessary will be

$\frac{\text{wattage}}{\text{voltage}} = \frac{1{,}000{,}000}{250} = 4{,}000$ amperes, and this would

need a very thick conductor to carry it. The cable would be far too thick and heavy to hang on an overhead line and very expensive because of the weight of metal needed.

Now suppose we use a transformer to step the voltage up

to 25,000, the current necessary will be $\frac{1{,}000{,}000}{25{,}000} = 40$ am-

peres, a current which can be carried in a comparatively thin wire, light enough to use in an overhead wire and considerably cheaper because less metal is needed.

The higher the voltage the smaller the current required

to transmit a given amount of power, and therefore the smaller the conducting wire.

In practice, generators produce a supply of electricity at between 6,600 and 11,000 volts and this is transformed to a 132,000 volt supply for distribution. From this voltage it is transformed down to 66,000, 33,000, or 22,000 volt supplies in subsidiary high voltage lines, and eventually is transformed down to the voltages needed in industry and in the home.

The main power line with the 132,000 volt supply is fed, through transformers, by all the main power stations in the country, and electricity can be distributed from it, through transformers, to users in all parts of the country. The system of power cables which connect all parts of Britain is called the Grid System.

It is evident that if many different power stations are to feed into the same transmission lines, all the alternators producing electricity must be exactly in step. If two equal alternators were $\frac{1}{100}$th of a second out of step and they fed electricity into the same cable, they would cancel each other out exactly.

Electric Motors

The simple principles of electric motors were explained in Chapter 10 of Book III. Mains motors are similar but more complicated. A motor for use on the mains consists essentially of a number of electromagnets attached to a shaft and revolving with it (the rotor), situated inside a ring of fixed electromagnets (the stator). The revolution of the rotor is caused by the repulsion of like magnetic poles and the attraction of unlike poles.

An AC motor may be similar in type to those working on DC, or it may be a synchronous motor. It may use

either a single-phase or a three-phase supply. Motors of the first type are often designed to run on either AC or DC. Then they are called universal motors.

Synchronous motors are motors in which the movement of the rotor synchronizes with the alternations of the main. While the frequency of the main remains constant at 50 cycles per second the speed of revolution of the motor will remain constant. Small motors of this type are used in electric clocks. Synchronous motors can only work on an AC supply.

A three-phase motor is one in which there are three sets of coils connected to the three line cables of a three-phase supply. In one fiftieth of a second a three-phase machine gets three sets of impulses to turn the rotor, whereas a single-phase motor only gets one set. A three-phase motor is more compact than a single-phase motor of similar power, and, because it gets three times as many impulses in any period of time, it runs much more smoothly. It is also more easy to control when speed and power regulation are necessary.

Three-phase motors are usually used for large motors in industry, but for smaller units either single- or three-phase motors may be used. Vacuum cleaners, hair dryers and other apparatus used in the home have single-phase motors in them, but very often the motors are universal and may either be used on a single-phase AC supply or on a DC supply. (Never connect a motor to a DC mains supply unless you are certain that it is either a universal or a DC motor of the correct voltage. If you connect an AC motor to a DC supply the result can be dangerous.)

THE FUTURE

The coal and oil reserves of the earth are being used up at an ever-increasing rate, and unless new and very

large deposits are found, they are likely to be exhausted in the course of a few centuries. This may not seem very important to us, but when we realize what a vast number of important chemicals and synthetic materials are obtained from coal and oil, we can see that the problem of the scientist is not simply to replace two sources of energy. He must also find other ways of obtaining hundreds of materials which we have come to look upon as essential. Since coal and oil are such valuable raw materials it would be sensible to conserve them by using all possible means of obtaining power from other sources.

While coal and oil are relatively plentiful the use of any other source of energy depends almost entirely on the cost of producing power from it. If, for instance, electricity could be produced on a large scale at a cheaper price per unit by some other form of energy, chemical energy would automatically be replaced. Up to the present the only source of energy which could replace chemical energy is the flowing water used in hydroelectric schemes. So far as Britain is concerned the possibilities of building hydroelectric plants are limited. Now, however, we can add atomic energy as a practical economical source of power. In Britain the main effort in improving power supplies is in the building of new atomic power stations. Even with the first atomic power station, the estimated cost of production was not much greater than that of the conventional coal or oil fired station. With experience in the building and functioning of atomic stations the cost should decrease. New ways of using the atomic fuel and the discovery of new fuels may help.

Although the steam turbine and generator plant are very nearly as efficient as they can be, there is a very large loss of energy between the initial fission of the

atoms and the conversion of the heat produced into steam. If a more direct way could be discovered of turning the atomic energy into rotary energy the process would be much more efficient.

If scientists learn to control the energy available from the hydrogen atom it will make an unlimited source of energy. So far the energy of hydrogen has only been used destructively, but so was the energy of uranium in the beginning.

The other sources of natural energy which might be developed if necessary, or which might be developed in parts of the world where they would be particularly economical, are wind power, the energy of the tides, volcanic energy and the energy of natural steam.

In this country the first two are the only possibilities but it seems unlikely that either will be very important if atomic energy is as successful as is expected.

For smaller power units, particularly in transport, engines using petrol and oil fuel are likely to remain in use for many years. Railways can be electrified and so use atomic energy indirectly, and we have seen that it is a practical possibility for at least large ships to use atomic energy plants. Its use in road transport and aeroplanes generally is unlikely unless new and revolutionary methods are discovered.

The possible line of development here would be the discovery of new ways of using electricity and particularly of storing it for use in motor transport. Electric trolleys and vans are used extensively for delivering goods in towns and it would need only moderate development to design a practical electric car which would be adequate for the average town motorist. Another possible development is the designing of smaller compression ignition engines working on gases and liquid fuels which may be

manufactured by chemists from common materials, or from the waste products of industry.

The general trend is to produce more and more electricity from other sources of energy, and to use the distributed electricity to replace coal and oil heating and small engines in individual power plants. One of the results will be that our towns will be less dirty and smoky and our natural resources will be used more economically and efficiently. Electricity may eventually supply all our needs for heat, light and movement, except possibly for long distance road transport, aircraft and ships.

TEN QUESTIONS TO ANSWER

1. Name (*a*) the main natural sources of energy and (*b*) the forms of energy needed in the home.

2. What is the use of the flywheel in the steam and internal combustion engine?

3. Describe what happens in each of the strokes of a four-stroke petrol engine.

4. Describe simply how a carburetter works.

5. Explain how a stationary gas turbine works.

6. Name the two types of aircraft engine that are gas turbines. What is the main difference between them?

7. Explain how a rocket is propelled.

8. What is the name given to substances having atoms which are the same chemically but are different in weight?

9. An AC voltage is continually varying. What do we mean when we talk about a 240 volt AC supply?

10. What is a transformer? What is its importance in the distribution of electrical power?

THINGS TO DO

1. If you have not already done so, revise Book Two, Chapters 2, 3, 7 and 8, and Book Three, Chapters 1, 9 and 10.

2. Mechanical energy, chemical energy, heat, light and electricity are five forms of energy. Find out how it is possible to convert each form into any of the other forms. Make a list in your book and, if possible, try each method in practice. For instance:—

To convert electrical energy into heat, pass an electric current through a wire.

To convert heat into electricity use a thermocouple.

(Find out what a thermocouple is, make one from copper and iron wires, and show that electricity can be obtained from heat.)

3. Read about the windmills and waterwheels used in the past. Find out the difference between a turret windmill and a post windmill. Find out the difference between undershot, breast and overshot waterwheels. Try to find a windmill and waterwheel within reach of your home. Visit them and write descriptions. Take photographs or make sketches to illustrate your description. Make working models of both windmills and waterwheels.

4. If you are allowed to make models in metalwork class, design and make a simple water turbine to be worked by water from the tap.

If you wind a piece of thread on the turbine shaft and suspend a weight from it, the turbine can be made to lift it. Time the rise of the weight through 1 ft. (or a greater distance if possible) and calculate the power at which the turbine is working. Try this with different weights and find the maximum power generated.

5. Newcomen, in 1704, invented the first steam engine. Find out how the Newcomen engine worked and what it was used for.

Find out about one of the early railway engines (for instance, the Rocket) and write a description in your book.

Find out how a modern steam locomotive works and compare it with the previous engine described.

6. Draw three diagrams similar to the diagram on page 125 to show the positions of the parts of the steam engine (*a*) when the

piston is just moving forward from the back end of the cylinder, (*b*) when the piston is just moving backwards from the front end of the cylinder, and (*c*) when the piston is in the middle of the cylinder

OR

Make a working model in cardboard or plywood of the diagram to show how the valve and piston move relative to each other.

7. If you are allowed to, make a simple steam engine in metal-work class

8 Find out how one of the following engines works:—
(*a*) a small compression ignition engine of the type used in model aircraft,
or (*b*) a motor of the type used as an auxiliary on a bicycle,
or (*c*) a motor scooter engine.

Write an account and illustrate with photographs and diagrams.

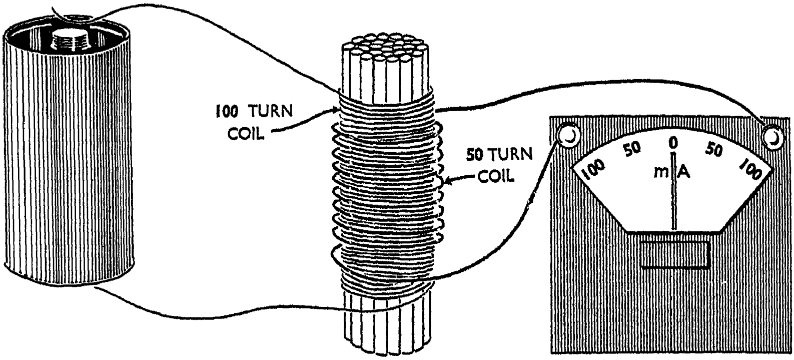
9. Obtain permission to examine a car engine. Draw a sketch to show the positions of the distributor, carburetter, petrol pump, dynamo, fan, spark plugs, radiator and water pipes, accelerator linkage and choke cable.

If you have the opportunity to see an engine with the cylinder head removed, study the movements of the pistons and valves as the crankshaft is turned.

10 Obtain a bicycle pump and place it with its opening pressed hard down on a piece of indiarubber on a bench. Pump energetically a dozen times keeping the pump pressed on the rubber as hard as possible. What happens at the lower end of the pump? Why?

11. Keep a scrap book about jet engines. Paste into it any cuttings about them you may obtain from newspapers and periodicals. Copy in any useful information or diagrams you may find in books.

12 Obtain some insulated copper wire, about gauge 30, and a bundle of short lengths (about 3 in.) of soft iron wire. Wind 100 turns of copper wire on to the bundle of iron wire leaving the ends long. Wind a second coil of 50 turns over the first. Connect



a meter and dry cell as shown in the diagram. Complete the cell circuit by tapping the free end of the wire on the centre terminal of the cell. Does the meter pointer move? If not, your meter may be too insensitive. Try another meter. Wind more turns on the secondary coil, repeat the test, and see what happens.

13. If your school possesses 12 volt AC and 12 volt DC supplies, carry out the following experiment Obtain a 12 volt 24 watt car lamp and a calorimeter or a small tin about 2 in. across and 3 in. high. (Check that the current required by the lamp can be taken safely from the supply.) You will also need a thermometer, a measuring cylinder and a clock with a seconds hand.

Solder wire leads about 18 in. long to the lamp contacts.

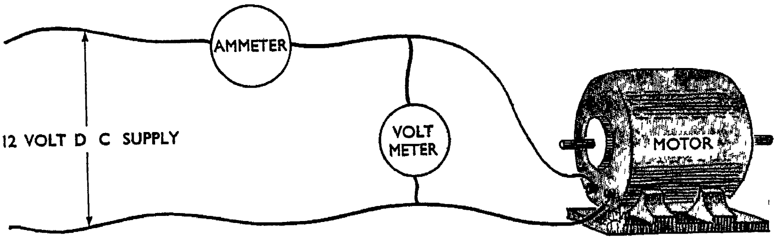
Place the lamp in the calorimeter and pour water from a measuring cylinder to cover it. (You will need to hold the lamp down under the water.) Make a note of the temperature, then connect the lamp wires to the AC supply. Find how long it takes for the temperature of the water to rise by 10 degrees Centigrade.

Disconnect the lamp from the supply, empty and dry the apparatus. Pour the same amount of water into the calorimeter as was used before and repeat the experiment with the lamp connected to the DC supply. Is the time nearly the same? If so, explain why.

If you have not 12 volt AC and DC supplies you can do the experiment by using a 6 volt bulb. You can use the 6 volt filament

supply from a radio transformer for an AC supply and a car battery or three 2 volt accumulators for the DC supply. You must only make connections to the transformer, and particularly to the mains, under the supervision of your teacher Incorrect or unsafe connections are dangerous.

14. Obtain a small electric motor which will work on a 6 or 12 volts DC supply. (Many electric motors used in aircraft equipment work well.) Take the motor to pieces and try to see how it works. Put it together again and connect it into a circuit with an ammeter to show the current passing, and a voltmeter to show the voltage across it. (Diagram below.) Switch on and note the readings of the meters Press on the spindle with a piece of wood



and slow the motor down until it stops, then release it. How do the meter readings change? What does this show?

If you can obtain a low voltage AC motor try the same experiment with this. You will need meters which read AC values.

15. Keep a scrap-book about atomic energy and new developments in power production. Paste into it any cuttings from newspapers, periodicals, etc., relating to the development in the uses of sources of energy. In particular keep a record of the building of atomic power stations and any information you may find about the type of atomic energy used by each, and the way in which the energy is converted into electricity.

SECTION 5

Photography

PHOTOGRAPHY IS ONE of the most important scientific processes in the world today. It is the basis of the great moving picture industry; newspapers depend on it for much of their interest; all industries depend on it in some way, if only for advertising; it is of vital importance in medical and scientific investigation; and it is one of the most popular hobbies.

Many of the men who are now considered expert photographers started as amateurs, and so we are going to talk about photography as a subject which you can adopt as a hobby if you like, and in which you may become an expert if you are sufficiently interested.

It is often said that photography is an expensive hobby, and of course it can be if you buy expensive cameras and apparatus, but it need not be if you are sensible. Photography is both artistic and scientific, and the artistic side, which is extremely important, depends on the person and not on the apparatus he uses.

THE PHOTOGRAPHIC PROCESS

All photographic processes depend on the fact that some materials are affected by light.

It has been known for more than two centuries that silver chloride, which is a white compound of silver and chlorine, darkens when it is exposed to light. Silver bromide, which is a compound of silver and bromine, is affected in the same way.

Other materials are affected in different ways. For instance gelatine which has been mixed with potassium bichromate is soluble in water, but if it is exposed to light it becomes insoluble.

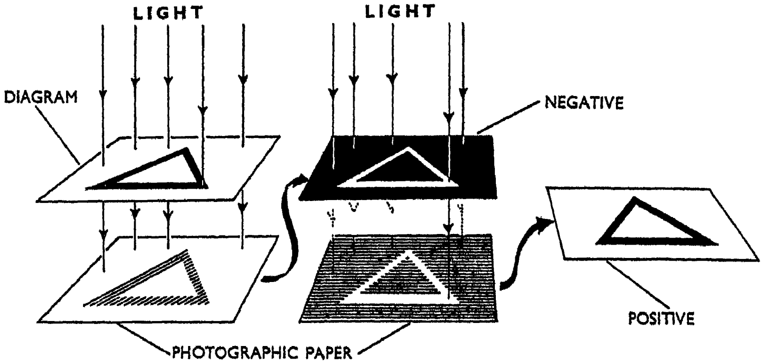
The most important of these chemicals in general use in photography is silver bromide. Plates, films and bromide papers are made when silver bromide and small amounts of other chemicals are formed in a solution of very pure gelatine and coated on to glass, cellulose or paper. The light-sensitive mixture is called an *emulsion*.

If a piece of photographic paper or film is left in the light it will darken. Bright sunlight will darken it more rapidly than light from an overcast sky, and light from an overcast sky will generally darken it more rapidly than artificial lighting. Even under the best conditions darkening takes a long time and chemical treatment has been found that makes it take place more rapidly. The process of using chemicals to cause the darkening is called *developing*.

Darkening is always greatest where the light is strongest, and no darkening occurs where there is no light.

NEGATIVES AND POSITIVES

Suppose we draw a pattern in Indian ink on a piece of tracing paper, place it over the sensitive surface of a piece of photographic paper and then expose it to light. Light will pass through the tracing paper and cause the sensitive emulsion to darken. No light will pass through the lines of Indian ink and so the emulsion underneath will stay white. The photographic image will be a white pattern on a dark background whereas the original drawing was a black pattern on a white background. The photograph is said to be a *negative* of the original.



To obtain a picture the same as the original it is necessary to pass light through the negative on to another piece of photographic paper and so get an image composed of black lines on a white background. The final image, which is a copy of the original, is called a *positive* or *print*.

To print a positive, light has to pass through the negative. Negative emulsions are therefore usually coated on to a transparent backing. *Plates* are obtained when the emulsion is on glass, and *films* when it is coated on to a cellulose material.

We see positives by the light reflected from them. Positive emulsions are therefore usually backed with white paper because white paper is the best sort of reflecting surface for our purpose. Often however we want to project our pictures on to a screen and, as the light in the projection lantern has to pass through the positive, the emulsion is coated on glass or cellulose. Transparent positives are called *diapositives* or *transparencies*, and when they are backed on glass they are called *slides*.

Negative materials are far more sensitive to light than positive materials.

DEVELOPING AND FIXING PRINTS

In the experiment we have just considered we obtained a negative and a positive of an original drawing. Let us suppose that both of these were exposed and then developed in one of the many developers on the market today. If they are left in the light the white areas will darken and in time they will both be completely black with no pattern on them. Silver bromide in the white areas not previously exposed to light is now being darkened by the action of light and developer together. Even if we dry the paper the blackening takes place. To obtain a permanent photograph the unexposed silver bromide must be removed from the paper before it is exposed to light. This is called *fixing* the print and is carried out by immersing the developed print in a solution of sodium thiosulphate (usually called *hypo*) for ten minutes.

The whole process of making a print is:—

(1) expose the photographic paper to light passing through a negative,
(2) place in a developer made up according to the manufacturer's instructions, usually for one or two minutes,
(3) rinse in water to remove surplus developer,
(4) place in fixing solution for ten minutes to remove the unexposed silver bromide,
(5) wash for one hour,
(6) dry.

Washing is very important and should be carried out in running water or water which is continually being

changed. Less than one hour could be enough but it is better to wash for too long rather than too short a time.

THE CAMERA

Most people are more interested in obtaining photographs of people and places than of line drawings, and to get negatives of such subjects a camera is necessary.

In Chapter 5 of Book I it was explained how the image is formed in a camera. If a piece of negative material is placed at the back of the camera so that the image is focused on it, the bright areas of the image will affect the emulsion most and the dark areas will affect it least. Middle tones in the image will affect the emulsion in an intermediate manner.

When the negative is developed it is found to be a complete reversal of the light and dark tones of the original picture. Light areas in the original will be black or nearly black in the negative, dark areas will be white or nearly white, and middle tones will result in greys in the negative. The negative translates the dark and light areas in the original, whether it is coloured or not, into a white, grey and black pattern.

Kinds of Camera

The main differences between cameras, apart from quality and price, lie in the type and size of negative material used and the method of viewing and focusing the picture to be photographed.

If we group cameras according to the type of negative material used we find there are three main types. They are roll-film cameras, plate cameras and 35 millimetre miniature cameras.

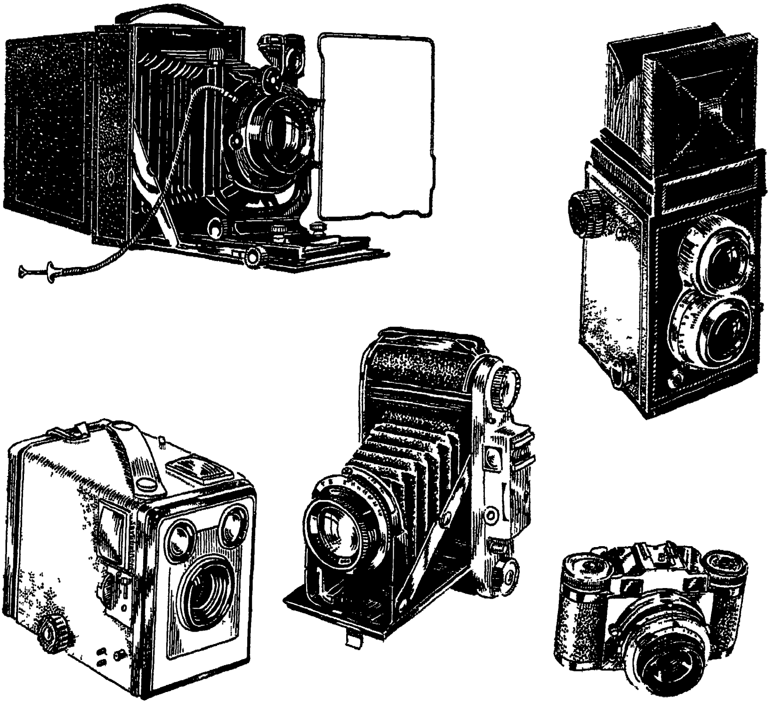
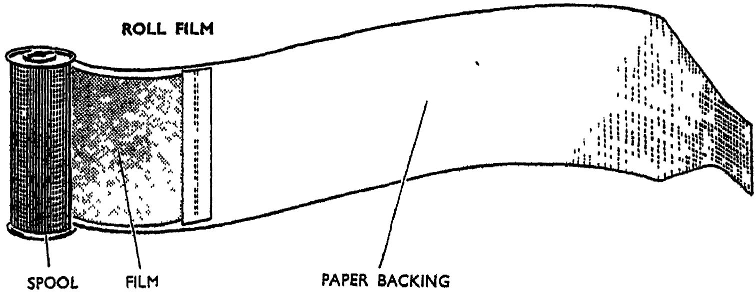


Plate camera Reflex camera
Folding camera
Box camera 3·5 mm. camera

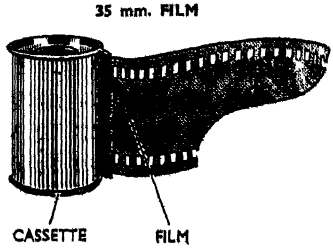
A roll film consists of a strip of sensitive film attached to a lightproof paper backing and rolled on to a spool. Any camera using film spooled in this way is a roll-film camera. A roll film can be loaded into, or taken from a camera in daylight, but it is safer to work in as poor a light as possible. The most popular sizes of roll film used are the 120 or 620 size which gives eight pictures $2\frac{1}{4} \times 3\frac{1}{4}$ in., and the 127 (Vest Pocket) size which gives



eight pictures $1\frac{3}{8} \times 2\frac{1}{2}$ in. Both spools may be used in cameras which give more pictures of a smaller size.

Plate cameras are similar to roll-film cameras except that they take plate negatives instead of roll film. Plates are more expensive than films and take up more space and so we find plate cameras used mainly for special purposes like press photography and technical photography.

Miniature cameras are so called not because they are small but because they take small photographs, so many roll-film and plate cameras could be classed as miniature. However, when we speak of a miniature camera, we usually refer to one in which the negative material used is 35 millimetre film similar to that used in taking moving pictures. The film is wound on a spool in a special light-tight container called a cassette in which it is loaded into



the camera. A standard length of this film is just over 5 ft. and on this 36 *Leica size* negatives 24 × 36 millimetres (about 1 × 1½ in.) are obtained.

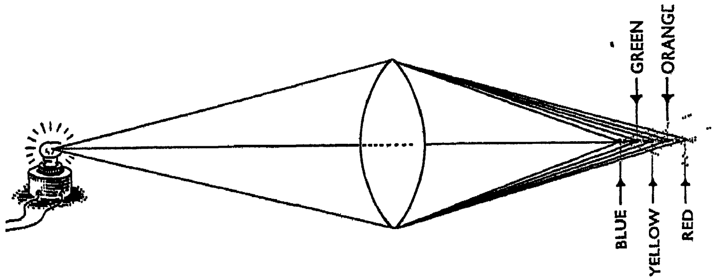
Reflex Cameras. These are cameras in which a special method is used for viewing and focusing the subject to be photographed. Roll-film, plate or miniature cameras may be of the reflex type.

In the single lens reflex camera, the image formed by the lens is reflected upwards on to a focusing screen on top of the camera. When the image is focused on the screen, the mirror can be moved up out of the way, and the image is then automatically focused on the plate or film at the back of the camera, and the exposure can be made.

In the twin lens reflex camera there are two lenses connected together. As the image from one is focused on the screen, the image from the other is automatically focused on the negative material.

Camera Lenses

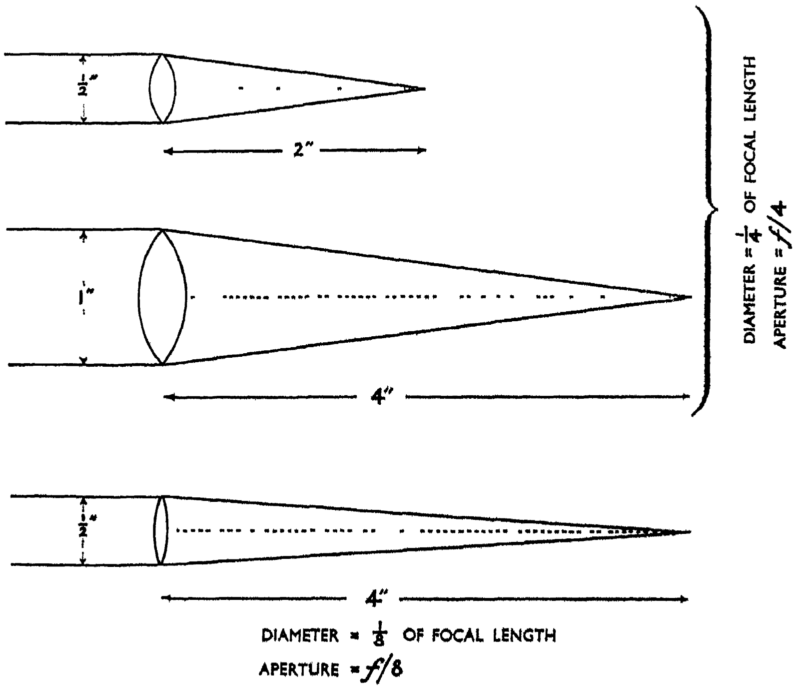
The most important part of a camera is the lens. If a distinct image is not obtained, the rest of the camera is useless, and if the lens does not collect enough light



exposures will have to be so long that only still subjects can be photographed.

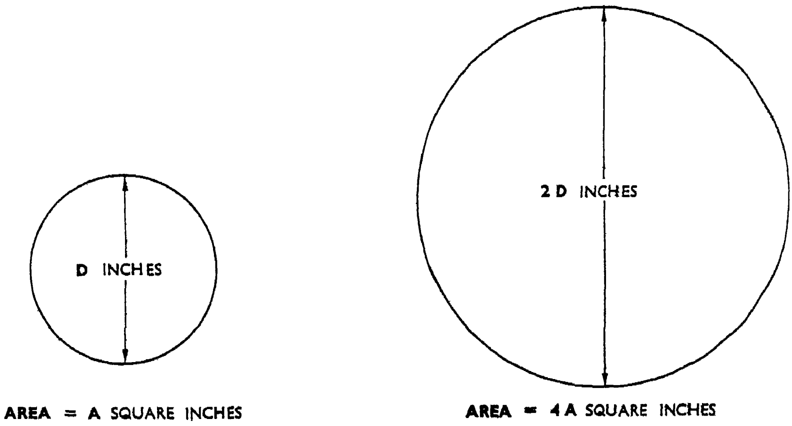
A single lens has many faults. It does not bring different coloured rays of light to the same focus and so you can focus it accurately for only one colour. The rest of the colours cause a blurred image. Another fault is that straight lines in the original object become curved in the image. In spite of these faults some cheap cameras with a single lens give quite good results.

In better cameras compound lenses are used. These are combinations of two or more single lenses of different types of glass designed to cut out the faults as far as possible.



The brightness of the image formed in a camera depends on the area of the lens collecting light, and the focal length of the lens. An $\frac{f}{4}$ lens (usually written f/4 or just f4) is one which has an opening of diameter equal to one quarter of the focal length, and an f/8 lens has an opening of diameter one eighth of the focal length. The fraction f/4, f/8, etc., is a measure of the light collecting power of the lens and is called the *aperture*. All lenses with the same aperture give an image with the same brightness.

An f/4 lens has an opening twice as wide as an f/8 lens so the area of its opening is four times that of the f/8 lens. The f/4 lens therefore collects four times as much light



and exposures with it will need to be only one quarter of the exposures required with the f/8 lens.

Bloomed Lenses. The lenses in most modern cameras are *bloomed* or coated with a very thin layer of a chemical which reduces reflections inside the lens systems. This has the effect of giving clearer images and may allow

shorter exposures. Bloomed lenses usually look blue or violet.

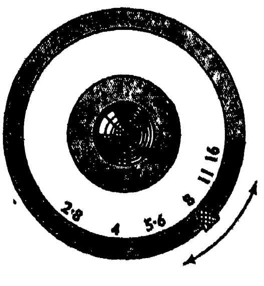
THE CAMERA CONTROLS

All cameras except the very simplest have means of altering the aperture of the lens, of altering the length of exposure, and of focusing on objects at different distances.

Aperture

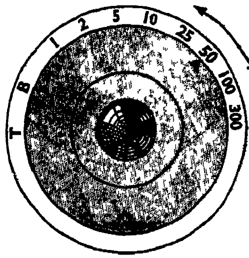
The aperture is usually adjusted by means of a movable pointer travelling over a circular scale on the lens mount. In the simpler cameras there will be only a few positions on the scale marked with descriptions like Heavy clouds, Light clouds, Sunshine. Such descriptions indicate that with the control in the first position the maximum aperture is being used, with the second position a smaller aperture and with the third position the smallest aperture is being used.

In better cameras you will see a scale like f/2·8, 4, 5·6, 8, 11, etc. in which each figure shows the size of the lens opening when the control is set on that figure. With any lens you can set it to any aperture smaller than a certain maximum value. A lens with a maximum aperture of f/2·8 is called an f/2·8 lens although it can be used at any smaller aperture. The scale is usually worked out so that at any position the light passing is half that passing at the previous position. An aperture of f/4 passes half the light of one of f/2·8, and f/5·6 passes half the light of f/4 and so on.



Exposure Time

The exposure scale in simple cameras has only three positions marked I, B and T. I stands for Instantaneous, and means that you can take a snapshot of a scene with that position. The exposure time is usually about one twenty-fifth of a second. B stands for Bulb time, and can be .used for short exposures. Pressing the trigger lever causes the shutter to open and it remains open till the lever is released. T stands for Time, and is used for long exposures. The first pressing of the lever opens the shutter and the second pressing closes it. Whenever you use the B or T positions the camera must be on a tripod or on some other firm support.



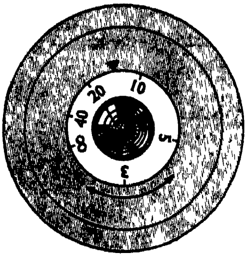
On better cameras the actual exposure times are shown and the scale may show a range of exposure times from 1 second down to $\frac{1}{500}$ second or less, as well as the B and T positions.

Focusing

There are several ways of focusing cameras. In plate cameras the whole lens panel can be moved forward and backward and you can focus the picture you want on a ground glass screen. The screen is replaced by the photographic plate when you take the picture.

In most cameras you are likely to meet, the focusing is carried out by screwing the lens, or part of the lens, out of the main lens mount. The distance at which the lens is focused for any position is marked on a circular scale. At one end of the scale is the mark ∞, or the syllable INF,

both of which stand for infinity. When the focus is in this position the photograph will be sharp for *all* distances beyond a certain minimum. From the infinity mark the scale usually has a series of numbers getting smaller and reaching 10 ft., or even 3 ft. or less, at the smaller end. Whatever the distance on the scale, that is the distance at which your subject should be, if you are to get the best possible photograph.



Some cameras have rangefinders on them. On looking through the rangefinder you see an image of the subject in two parts. You can adjust the rangefinder until the two parts fuse to make one complete image, then the distance shown on the scale is your distance from the subject. You focus your camera to that distance before taking the photograph. In other cameras the rangefinders are coupled. This means that as you make adjustments to find the range, the camera lens, which is connected to the rangefinder mechanism, is automatically focused on the subject.

In practice, whatever your focusing distance, there is always a certain distance behind your subject and a certain distance in front of your subject which are also in focus in the photograph. The total distance in focus is called the *depth of field* of the lens for the conditions of the photograph. Many cameras have devices on them from which you can find the depth of field for any setting of the camera. If there is no depth of field scale you must remember that

(*a*) for larger apertures,
(*b*) for photographs of nearer objects,
and (*c*) for lenses of longer focal length,

the depth of field becomes smaller and so you must be more careful to focus accurately.

BUYING AND USING A CAMERA

If you are a beginner buying your first camera obtain a roll-film camera using 120 or 620 film and giving either $2\frac{1}{4}$ in. square or $2\frac{1}{4} \times 3\frac{1}{4}$ in. size of picture. You can obtain worth-while contact prints from these negatives whereas anything smaller would need enlarging.

If you are fortunate enough to be able to buy a good camera with complicated controls, the best thing to do until you become used to using them is to fix the controls and use the camera as though it were a simple box camera. Set the aperture at f/11 and the exposure time at $\frac{1}{25}$th of a second, then all you have to do when you want to take a photograph is focus on the subject and press the release.

Each time you take a photograph make a note of the subject, the conditions of weather and light, the film used, and the camera control settings, so that from the faults that appear in the final prints you can learn to adjust the camera to give you a good print nearly every time.

Camera Accessories

There are a number of accessories which can be obtained which are not absolutely necessary but which can help your photography considerably.

Beginners often jerk the camera when they are taking photographs and blurred prints result. A *flexible cable release* can be useful in preventing troubles of this kind.

For exposures longer than about $\frac{1}{25}$th of a second a firm support is needed for the camera and a *tripod* may

become necessary. When you buy a tripod make sure it is rigid and solid.

Lens hoods and filters can help you to get better photographs. The lens hood prevents light from reaching the lens from the side and is particularly useful when you are taking pictures towards the light, but often gives crisper negatives even in ordinary conditions.

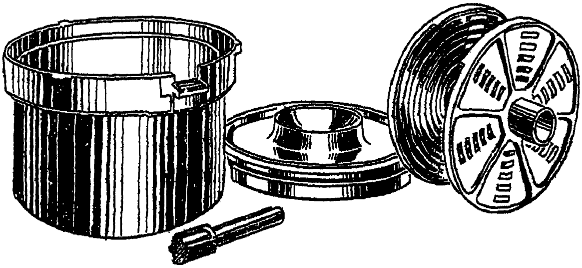
Coloured filters of gelatine or glass are used to pick out or to suppress a particular colour of light coming from the subject. The most commonly used filter is the pale yellow cloud filter This hinders the passage of blue light but passes the rest. When you take a photograph of a cloudy sky the light from the clouds is passed without hindrance but light from the blue sky is suppressed. The result on the final print is to show light clouds against a dark sky. Clouds do not usually photograph well unless you use a filter.

If you wish to take close-up photographs of small models, or objects like stamps or coins, it is necessary to have a supplementary lens. Lenses of this type which allow you to focus on objects at a distance of a foot or even less, are available to fit most cameras.

DEVELOPING NEGATIVES

The development of a film is more difficult than that of a print because it is so much more sensitive to light and its length makes it awkward to handle. The most satisfactory way of developing film is to use a special developing tank. Most of these consist of a plastic pot with a light-tight lid in which can be placed a plastic reel with a spiral groove in it to take the film. In total darkness the film is removed from its spool and separated from the paper backing (or taken from the cassette in the case of a 35 mm.

film). Still in darkness the film is slid into the spiral groove of the tank reel, the loaded reel is placed in the tank and the lid is put on. After that, all the chemical solutions can be poured into and from the tank without



opening it and in full light. The process usually followed is:—

(1) Fill the tank with clean water to wet the film, so that the developer acts evenly;
(2) empty out water and replace with developer and leave for a time depending on the film and developer;
(3) empty out developer and pour in clean water to rinse out the remaining developer;
(4) empty out water and pour in the fixing solution and leave for ten minutes; then
(5) empty out the fixer and wash the film in running water.

A satisfactory method of washing is to take the lid off the tank (the film has been fixed and can no longer be affected by light) and stand the tank in a sink letting water from a tap run gently into and out of it for about fifteen minutes. The effectiveness of the washing is made more certain if the tank is emptied of water a few times during the period.

There are a number of precautions you must take. You must get all your solutions as near the same temperature as possible and this depends on the temperature at which the developer must be used.

Never Get Your Solutions Muddled

If you put fixer into the tank instead of developer, the film is ruined and nothing can be done to restore it. It is never worth while using old developer unless you have tried it first on something that does not matter. Stale developer can completely ruin a film. Remember that the negatives exposed in your camera can never be repeated exactly, they are precious and it is false economy to skimp their development and fixing.

Films can be developed by hand using a dish of developer but the method is not very satisfactory. Plates, on the other hand, are generally developed in dishes of solution, the steps in the process being the same as those used in tank development—wetting, development, rinsing, fixing, washing and drying. The developing solution is used stronger to make the time of development shorter. Unless you use a light which is safe for the plates you are developing, processing must be carried out in the dark until the plates have been fixed.

TYPES AND SPEED OF PLATES AND FILMS

Apart from their size the two things we want to know about plates and films are (1) their speed, and (2) the way in which they are affected by different colours of light.

Speed

The less the light needed to obtain a good negative the

faster the emulsion is said to be. To expose negatives accurately it is necessary to know the speed of the plate or film being used.

There are a number of scales used for indicating the speeds of negative materials but it is impossible to give accurate figures connecting them because so many things affect the actual working speed of an emulsion. The following table gives a list of very approximate equivalents between the scales and shows the types of film falling under the various speed headings:—

Scheiner Log Exposure Index Kodak Speed Number	*DIN*	*Arithmetic Exposure Index Weston Speed Number*	*H. and D*	*Ilford Film Group*	*Types of Film*
35°	25/10	250	6,000	G	High sensitivity panchromatic films
32°	22/10	125	3,000	F	
29°	19/10	63	1,500	E	"Chrome" films—Selochrome, Verichrome, etc. Fine grain pan films—Ilford FP3, Kodak Plus X, etc
26°	16/10	32	750	D	Fine grain panchromatic Ilford FP Special, Kodak Panatomic X
23°	13/10	16	375	C	Extra fine grain pan films—Ilford Pan F, etc
20°	10/10	8	188	B	Slow materials used for special purposes.
17°	7/10	4	94	A	

Colour Sensitivity

The earliest photographic emulsions were sensitive only to the blue light in the spectrum. Light of any other colour had practically no effect on the emulsion and so a negative on development would appear quite clear for any other colour but blue. A print made from the negative would be black for any colour other than blue. If we use such a material we will obtain a recognizable photograph but it will not look right. Colours which appear equally bright to the eye are very different in brightness in the photograph. Emulsions of this type are still used and plates or films coated with them are called *ordinary* plates or films.

Orthochromatic emulsions are those which have been treated so as to be sensitive not only to blue but also to green and some yellow light. These give better results but red objects still appear black in the print although they might be very bright in colour.

Plates and films sensitive to all the colours of the spectrum are called *panchromatic*. These give the best results of all because the different brightnesses of colour in the original picture are reproduced as corresponding brightnesses in black and white in the final print.

Although there is an appreciable overlap in speed, ordinary emulsions are generally the slowest, orthochromatic emulsions are of middle speed, and panchromatic emulsions are the fastest which can be obtained.

NEGATIVE CONTRAST

When a film or plate is developed the negative obtained depends on the type of film, the amount of exposure and the method of development.

A good negative should be quite clear at any points which correspond to black objects or very dark shadows in the original scene, and should be a solid black for white or very bright objects. There should also be a large number of middle (grey) tones corresponding to the various brightnesses of all the other objects in the scene. Such a negative would be called a *normal* negative.

If the negative shows little difference between the lightest and darkest regions (the lightest areas are not clear or the darkest areas not full black) it is said to be a *soft* negative.

If the negative has clear areas and black areas and very few grey tones in between it is said to be *hard* or *contrasty*.

To obtain the best possible print from a negative the correct grade of paper must be used.

Photographic Papers

There are many different kinds of photographic paper used for different purposes, but the two types we will consider are a slow paper called *gaslight* or *contact* paper and a fast paper called *bromide* paper. Gaslight paper can be handled in ordinary room lighting provided it is kept in the shadow, but bromide paper can be used only with a special safe light.

Both of these can be obtained with various types of surface from the glossy surface used by professionals to a rough matt surface.

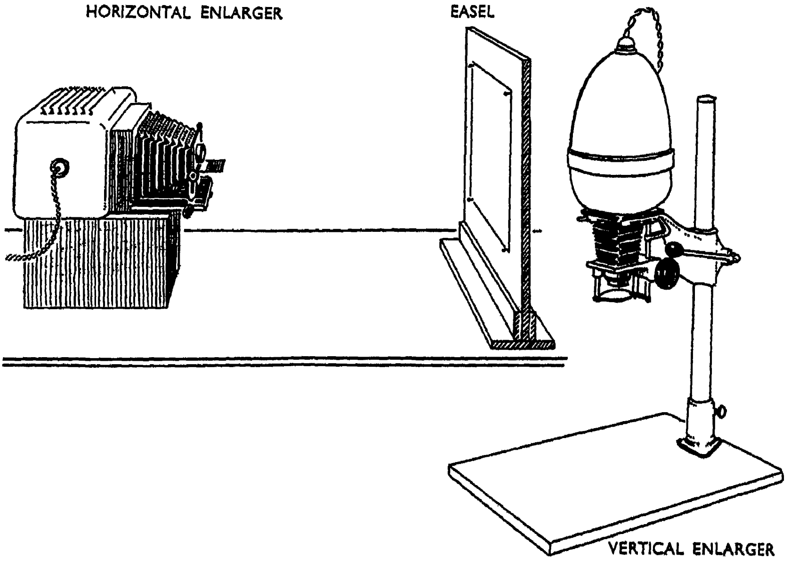
Printing papers are also made in various degrees of contrast so that any negative can be matched to give a good print. A paper which gives a correct picture from a normal negative is called a *normal* paper. To obtain a correct print from a soft negative, contrast must be added

and a *hard* or *contrasty* paper must be used. To obtain a correct print from a hard negative the contrast must be cut down to some extent and a *soft* paper must be used.

There is a paper called Multigrade which can be used with almost any negative. The paper is soft, normal or hard according to the colour of the light affecting it, and colour filters of different shades of yellow are used to match the paper to the negative.

ENLARGING

When you have mastered the technique of contact printing you will wish to try enlarging. An enlarger is only a projection lantern (what used to be called a magic lantern) with a special lens in it. The enlarger consists of a lamphouse containing a special pearl bulb, a condensing



lens to collect as much light as possible and send it through the negative, and a lens to throw an image of the negative on to a sheet of photographic paper. In some enlargers the condenser is replaced by opal glass in order to cut down cost but this is not a good idea as opal glass wastes so much light.

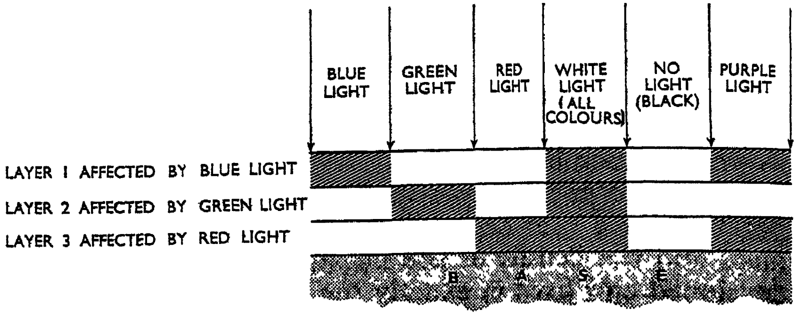
The photographic paper is exposed to the image of the negative for a time depending on the degree of enlargement and the density of the negative, and after that it is developed and fixed in exactly the same way as a contact print.

The type of enlarger most commonly used is the vertical or upright enlarger. Horizontal enlargers can produce just as good results but take up more space and are not so convenient in use. However if you cannot afford to buy an enlarger you might like to try making one and a horizontal enlarger would be the best to start on.

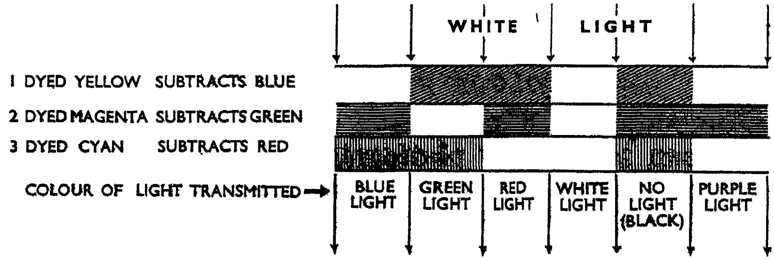
COLOUR PHOTOGRAPHS

Anybody with a camera and a spool of colour film to fit it can take colour photographs. The colour film is exposed as though it were a slow black and white film, and when the whole film is exposed it is sent off to the manufacturer to be processed. To process colour film himself a photographer needs to be very experienced and so we do not intend to go into processing details. However, you should know why a colour film gives a fully coloured image of the original.

Most colour films used by amateurs today are of the integral tripack type. That means that the film really consists of three films in one—the backing has on it three separate layers of emulsion each of which is affected by one colour of light only, one by blue, one by green and



one by red. On processing, the region affected by light in each layer is bleached away, and the region not affected by light in each layer is dyed the complementary colour to the light affecting that layer. The diagram shows how the different colours are reproduced.



Different manufacturers have different ways of separating out the coloured light in the film and of dyeing the three layers during processing.

TEN QUESTIONS TO ANSWER

1. Name the light-sensitive chemical which is used in most photographic emulsions.

2. Why is it necessary to fix positives and negatives?

3. What is meant by the statement that a lens has an aperture of f/4? If the aperture is reduced to f/5·6 what fraction of the original light will pass through?

4. Explain simply what is meant by the expression depth of field.

5. Describe how a single lens reflex camera works.

6 What is a cloud filter, and why does it cause clouds to show up in a photograph?

7. Write out, in order, the steps you would follow in developing a film in a tank.

8. What are (*a*) orthochromatic, (*b*) panchromatic films?

9 State what contrast of paper you would use to obtain a print from (*a*) a hard, (*b*) a soft, and (*c*) a normal negative.

10. To what colours of light are the three layers of a colour film sensitive? What colours are the layers dyed when the film is processed?

THINGS TO DO

1. Read Book I, Chapter 5 and pages 83 and 84, and Book III, Chapter 8, and revise work on cameras and lenses.

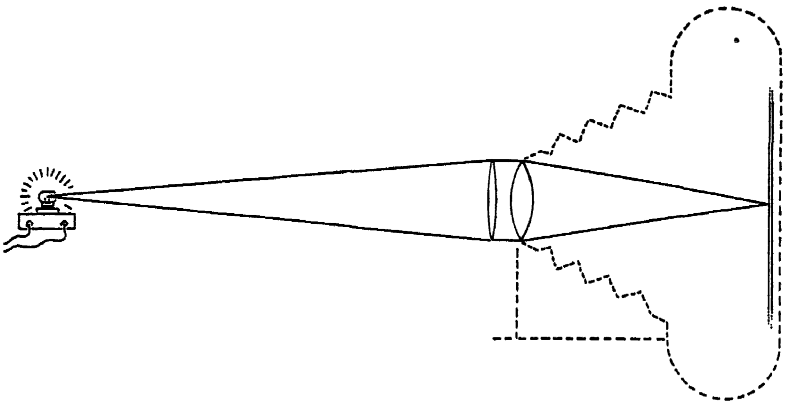
2. Obtain a lens of focal length between 2 and 4 in., and another of focal length 1 ft or more. Find the focal length of each lens.

Set up the short focal length lens to form an image of a distant object on a screen, then place the second lens in front of the first, and using a lighted torch bulb as an object, find the position of the object, in front of the pair of lenses, which gives a clear image on the screen. Measure the distance from the object to the second lens. What is this distance?

If you imagine the first lens as a camera lens and the screen as the film in the camera you can see that the second lens is acting

as a close-up lens. Notice that if the camera is focused at infinity (for distant objects) the object focused with a close-up lens is the focal length of the close-up lens away. Simple lenses like spectacle lenses may be perfectly satisfactory as close-up lenses.

Carry out the experiment with different pairs of lenses and, if possible, with a camera with a ground glass screen instead of the



first lens and cardboard screen Experiment to find out what effect focusing the camera on near objects first has on the nearness of objects which can be focused using the close-up lens.

3. Obtain pieces of red and blue filter (coloured gelatine or glass) and using the lens, screen and bulb of the previous experiment, set up the apparatus so that light from the bulb passes through the blue filter before striking the lens. Adjust the screen until the blue image obtained is focused. Leaving the lens and light source in position, replace the blue with the red filter and adjust the screen until the red image obtained is in focus. Is the screen in the same position in both cases?

Try this for different lenses and different filters.

If you can obtain a colour corrected camera lens try the experiment with that.

4. Arrange your apparatus in front of a window at such a distance that the image of the window framework fills the screen.

Do straight lines in the framework appear as straight lines in the image? Try this with different lenses, including a camera lens if possible.

5. EXPERIMENTS WITH PRINTING PAPER

You will need:—

A packet of normal gaslight paper ($2\frac{1}{2} \times 3\frac{1}{2}$ in.), a packet of suitable developer powder and some fixing salts, three small dishes and a bowl, a thermometer, liquid measures and a watch or clock with a seconds hand.

Photographic chemicals can be made up far more accurately and cleanly by the various manufacturers than by the amateur and particularly by a beginner. We do not intend therefore to try to teach the complicated chemistry of photography. Learn to use the special photographic chemicals on the market first and gain sufficient experience to judge and compare their properties before you start experimenting on your own.

It is better to use the products of only one manufacturer, say Ilford or Kodak, in the first instance, then when you have gained experience you can compare the materials of other manufacturers with those you know. When you find something better, transfer to that until you discover something better still. All photographic chemicals sold have with them instructions for mixing and for using, so, whatever you buy, read the instructions carefully and follow them as exactly as possible. A manufacturer generally knows far better than anybody else how his products should be used.

The only difficulty likely to occur in making up solutions is the difficulty of the units in which measurements are quoted and made. Many manufacturers now give both English and Metric units in their instructions but if they do not it is useful to know the connection between the two systems in case your apparatus is not marked in the units used in the instructions. The English units of volume usually used are the pint and the fluid ounce.

One fluid ounce = $\frac{1}{20}$ pint.

The Metric units of volume are the litre and the cubic centimetre or millilitre.

1 litre = 1,000 cubic centimetres (millilitres).

The English unit of weight used is generally the ounce and the Metric unit is the gramme

1 ounce weight = 28 4 grammes (30 grammes is accurate enough for many purposes).

1 pound = 456 grammes.

1 fluid ounce = 28·4 cubic centimetres (approximately 30).

1 pint = 568 cubic centimetres.

The dishes required need only be big enough to take the size of paper you are using. If you have proper photographic dishes use them, otherwise any enamel dishes or enamel or china saucers will do at this stage. Ordinary shallow cake tins make inexpensive dishes up to almost any size if you coat the inside with paraffin wax or candle wax. Melt some wax in the tin then move it around until the entire inner surface is covered with a thin layer. Allow it to cool and the dish is ready for use.

With all apparatus and materials ready, proceed as follows:—

Make up (*a*) the developing solution and (*b*) the fixing solution according to the instructions given with each. *Precaution.* Wash your measures after each chemical has been in them. If fixer gets into the developer it will be spoiled. It is safest to mix the developer first, then the fixer. Put the made up solutions into storage jars and label them clearly with the type and strength of solution.

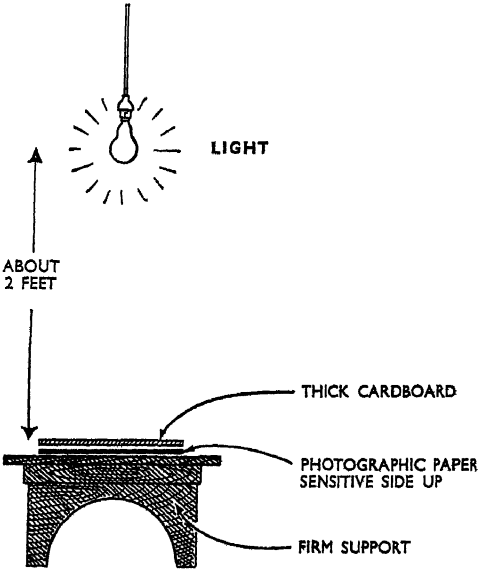
Set out your dishes and bowl side by side on a bench or table so that they are in shadow from the electric light. Pour out solutions so that you have the following arrangement:—

dish of developer	dish of clean water	dish of fixer	bowl of clean water

From now on you must work in artificial light only (no daylight).

Open the packet of paper in shadow and cut one piece lengthwise in half. One side of the paper is shiny and the other is not. The shiny side is the sensitive emulsion side. Take one of the cut pieces of paper, cover it with a piece of thick cardboard or a sheet of any lightproof material, and place it close to the light you will

use for exposing. It is usual to work at about 2 ft. from a 60 watt bulb but this first experiment will help you to find the exposure time for your own particular conditions.



Remove the cardboard from the photographic paper and after 5 seconds cover a quarter of the paper strip with it, after 10 seconds move it to cover half the strip, after 20 seconds move it to cover

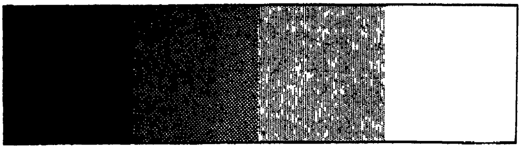
TIME OF EXPOSURE	40 SECS	20 SECS	10 SECS	5 SECS

three-quarters of the strip and after 40 seconds cover the strip completely and remove from the light. Place the strip in the developer, making sure it is thoroughly wetted, and move it about. Watch the way in which the image develops and, at the end of the time recommended in the instructions, rinse the strip in the dish

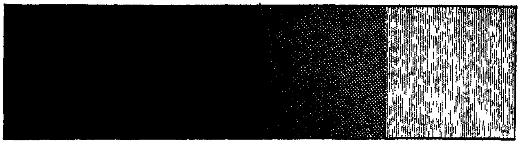
of water and place it in the fixer. After a minute or so in the fixer it can be examined in the light but for complete fixing it must stay 10 minutes and then be transferred to the bowl of water to wash. If a sink with running water is available it is better to use that than the bowl, but a bowl in which the water is changed a dozen times will wash the prints adequately.

Your final print will probably look like A in the following diagram, one end being white or near white and the other end

A



B

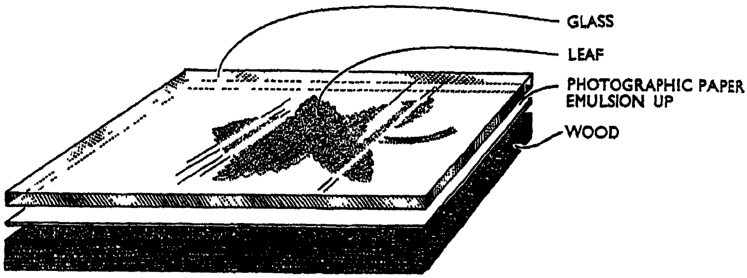


black or nearly black. What you are trying to find is the least exposure from the bare light which will cause the paper to develop a full black image. If the 40 second area of the paper is a full black, the other areas being lighter, the exposure time you are trying to find is probably somewhat less than 40 seconds but is certainly greater than 20 seconds. You could carry out another test strip experiment with exposures between 20 and 40 seconds to get a more accurate result. If the test strip looks like B the time required is 20 seconds or less, but certainly greater than 10 seconds. If the strip develops black all over either 5 seconds is too long an exposure or you have exposed it accidentally to light apart from the trial exposure. Repeat the experiment and if the result is still black try exposing further strips at a greater distance from the light. If the final print shows no blackening at any point try another strip much closer to the source of light.

Stick your test strips into a book which you will keep as a photographic record book and write beside each

the type of paper used—make, type, contrast and surface;
the wattage of the source of light;
the distance from the light;
the developer used—temperature and time of development.

6 Obtain some small leaves, the thinner and more delicate they are the better, a piece of wood or stout cardboard and a



piece of glass, both the size of your printing paper or bigger. Put a piece of printing paper back down on the wood, place a leaf on the sensitive surface and the glass on top of the leaf. Pressing the edges of the glass and wood together will flatten the leaf Expose to the light in the position used in experiment 5 for the time found to give a black print. Develop and fix. You will have an image of the leaf and if the exposure is right and the leaf not too thick, all the veins in the leaf will appear quite clearly.

Try this for different leaves, for a piece of patterned lace and for anything else similar you can think of. Various types of open nylon weave give interesting patterns. Stick all your samples in your record book with full details of how they were produced.

7. Obtain a picture of a leaf as in experiment 6, showing as many details as possible. This is a negative The actual leaf is dark against a light ground, the picture is light against a dark ground. After the negative has been washed thoroughly dry its surface with clean blotting paper and place it back downwards on a piece of fresh photographic paper. Hold between the wood and glass and expose to the light for three times the length of exposure used before. Why is the increase in exposure necessary in this

case? Develop and you will get a positive of the original subject. The positive has many faults. It is probably not very distinct and the image may be mottled. The mottling is due to the fibrous nature of the paper negative being used. To get a good positive the negative must be based on a transparent material.

8. Obtain gaslight papers of soft and hard grades and repeat experiments 5 and 6 with them. In what ways do the test strips differ from those of experiment 5? Do some grades of paper appear faster than others or not? Which grade gives the best leaf images? Paste all your specimens in your record book with full details.

9. Obtain some old (but clean) negatives. Most families have dozens of negatives in which they are no longer interested. Pick out one containing some full black areas, some clear areas and a good range of middle tones. Place the negative dull side down (the dull side is the emulsion side) on a piece of normal paper, sandwich them between the piece of wood and glass and expose for the time found in experiment 5. On developing and fixing the print should have some full black areas, some clear white and a good range of grey tones. It should look right. If it is too dark or too light you must try again with a different exposure time.

Now print the same negative on a hard and on a soft paper using the times found in experiment 8. The print on hard paper will be too contrasty and *chalky* in appearance and the print on soft paper will be flat and uninteresting. Stick negative and prints in your record book giving details. A normal negative needs a normal paper.

Next find a negative which is flat and thin. Print this out on the three types of paper and stick the results in your record book. The best print will be on the hard paper. A soft negative needs a hard paper.

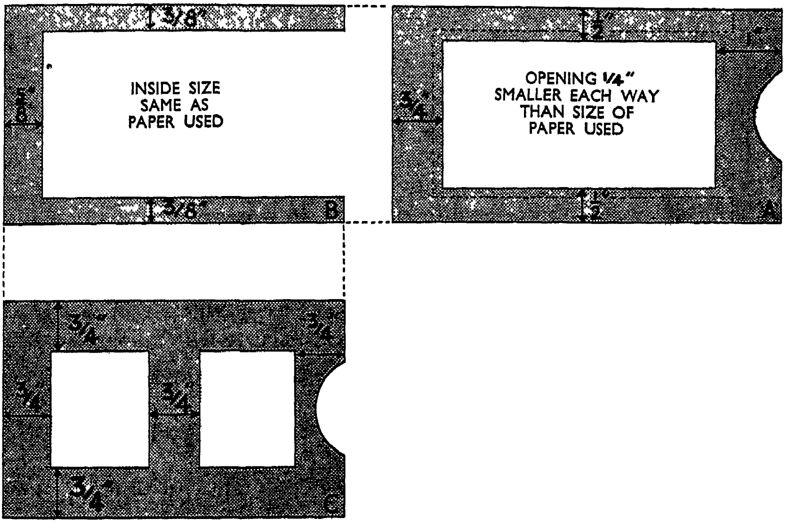
Now find a hard negative and repeat the process to show that a soft paper is needed.

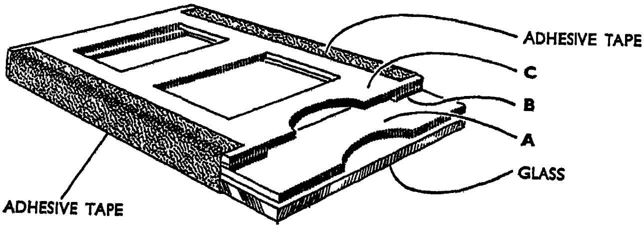
10. PRINTING FRAMES

Your prints will not look very good because they have uneven black borders round them. You can improve them by cutting the

borders off, or you can buy a printing frame for the size of print you are making. The frame enables you to obtain prints with even white borders like those found on professional prints.

If you prefer to make your own apparatus, the following paragraphs describe a design of frame which we have used





successfully for many years, which costs practically nothing to make, and which is better in many ways than the conventional bought article.

Cut pieces of thin card (smooth postcards are of about the right thickness) to the shapes shown in the diagram. Notice that the

sizes depend on the size of printing paper you wish to use. A different frame is required for each size of paper. Stick pattern B on pattern A in the position shown by the dotted line on A. Stick C squarely on B. Use as little adhesive as possible so that none can squeeze into the space between A and C into which the photographic paper should slide easily. Paint the front side of A with Indian ink, then attach the paper holder to a piece of glass the same size with adhesive tape down both side edges. To use the frame place a negative between the cardboard and the glass, shiny side to the glass. Adjust the negative so that it is masked correctly and, if necessary, tilt it a little to get upright lines upright, or horizontal lines horizontal, in the final print. Slide a piece of photographic paper into position emulsion side towards the negative. Make sure it goes right into the bottom channel of the frame. It is a good idea to press the back of the frame on to a piece of sponge rubber or felt while exposing and then the negative will be kept in close contact with the paper.

11. PRINTING BOXES

A printing box is a special source of light used instead of the room light for printing. You can make a very simple printing box from any small wooden box which has an open top bigger than the biggest contact print you are likely to want to make. Paint the inside of the box white and screw a batten holder to hold a 15 watt electric light to the middle of the base inside. Take the flex from the batten holder to a switch on the side of the box and have about two yards of flex outside the box with a plug on the end to connect to the mains electricity supply. Obtain a piece of opal glass the size of the top of the box (ordinary frosted glass is not suitable) and fix it with adhesive tape round the edges to cover the top of the box. To use the box put a negative and paper in your printing frame, place it glass downwards on the opal glass of the printing box, and press it down with a pad of sponge rubber or thick felt. Use the switch to turn the exposing light on and off. You will have to carry out tests similar to those described in experiments 5 and 6 to find the exposure time.

12. EXPERIMENTS WITH BROMIDE PAPER

In addition to the apparatus you have used in the previous experiments, you will need packets of soft, medium and hard bromide paper, some developer suitable for bromide paper and a safelight. It is possible to buy a special coloured bulb which can be used in an ordinary electric light socket. Carry out experiments 5 to 9 using bromide instead of gaslight paper. Bromide paper is much faster than gaslight paper so you will have to give much shorter exposures or work at a greater distance from the light.

13. TESTING THE FOCUSING SCALE OF A CAMERA

Obtain a piece of frosted glass which just covers the opening at the back of your camera where the negative usually goes. Fix the glass in place with rubber bands, frosted side towards the lens of the camera. Put the exposure control on T and open the shutter. The image of the scene in front of the camera will appear upside down and back to front on the screen. Set the focusing control at, say, 10 ft. and move with your camera until the image of the frame of a window, or any other suitable subject, is in focus on the screen. Measure the distance between the camera and the window. Is it 10 ft.? Is it inside the depth of field for your lens focused at 10 ft.? Does the image on the screen coincide with the picture seen through the viewfinder? Test for different focusing distances on the scale. If the camera has a coupled rangefinder you must check whether or not the focusing distance found through the rangefinder gives correct focus on the screen and agrees with the distance on the focusing scale at the same time.

If you think your camera is faulty in any way do not try to make adjustments yourself—it is a job for an expert and you can easily ruin a camera through being ignorant of the correct way of dealing with faults.

NEVER unscrew a lens or attempt to adjust it in any way. Always remove dust with a soft brush, scrubbing with a cloth will damage the lens, particularly if it is bloomed.

NEVER try to adjust the shutter timing mechanism or oil the shutter because it sticks. Even the lightest oil will completely jam it.

NEVER try to adjust a coupled rangefinder.

Of course, if you have an old camera that does not matter, you can learn a lot by taking it to pieces then trying to put it together again and adjust it.

14. LEARNING TO USE YOUR CAMERA

Obtain a used film of the type used in your camera and practise loading and turning the film on. Practise until you can load and unload the camera with your eyes shut and in the dark. Films sometimes jam and it is useful to be able to unload, respool and reload the film in the dark.

Obtain a Selochrome, Verichrome or similar film and some means of estimating exposures. There are many pieces of apparatus on the market to help you judge exposure, from the expensive photo-electric meters to quite cheap slide rule types of calculator. The cheapest aids of all are the exposure tables issued free by some manufacturers of films and they are adequate for most purposes. Load your camera and choose a number of subjects to photograph which will test the range of your camera. Choose some distant views, some nearer, and at least one as close as the camera will focus, making sure in each case that there is detail which will test the quality of your lens. For each photograph find the exposure necessary, using exposure tables or a meter. You will find there are always a number of different apertures and exposure times which will give the same result. It is best to choose the shortest possible exposure time for which the corresponding aperture gives sufficient depth of focus for your purpose.

When you have finished the spool send it to be processed by a professional. In this way you can be reasonably sure that any faults in the negatives are due to the camera or to your photography and not due to mistakes you may make in developing and printing. You will also have a standard against which to compare your own attempts at processing.

Make a note in your record book of the type of film and of the light conditions, the subject, the aperture and the exposure for each photograph.

15. DEVELOPING FILMS

Until you obtain a developing tank you can get your films developed by a professional and you can print them yourself. When you do get a developing tank, practise loading it with an old used film if you can get one that has not been cut up into separate negatives. If you cannot it is worth while to use a new film. You must be able to load a film into the tank in total darkness without buckling it or tearing it and without fingering it any more than is absolutely necessary. At the expense of a new film you can save yourself from damaging films with precious pictures on them, at a later date.

When you can load the tank, try developing your first film. Obtain a developer suitable for tank use and follow the maker's instructions and the information given on page 177.

16. Manufacturers of photographic chemicals and equipment issue a great deal of literature for advertising purposes. The pamphlets and books often give not only information about the manufacturers' products but also general photographic information, and they have the advantage of being issued free or very cheaply. Many books on photography, costing far more, give less useful information than the pamphlets.

Obtain information from advertising literature, books and photographers with more experience than you, about the following subjects. Make notes in your record book so that you have all the useful information in one place when you need it. Paste into your books any useful diagrams or tables you find in the pamphlets. You may find articles and information about all subjects in photographic periodicals like the *Amateur Photographer*.

(1) Table-top photography and the photography of models.
(2) Filters and their uses.
(3) Document photography and copying. Find out how reflex and direct positive photographic papers are used.

(4) Exposure aids. These come under four main headings—photo-electric exposure meters, visual exposure meters, exposure calculators and exposure tables. Obtain pictures and information about the construction and use of at least one of each of the first three types. Obtain information about at least one type of enlarging exposure meter.

(5) Setting up a photographic darkroom. Safelights and their use

(6) Colour photography.

(7) Indoor photography by ordinary lighting, photofloods and flashlight. Find out what is meant when a camera is said to have a synchronized shutter.

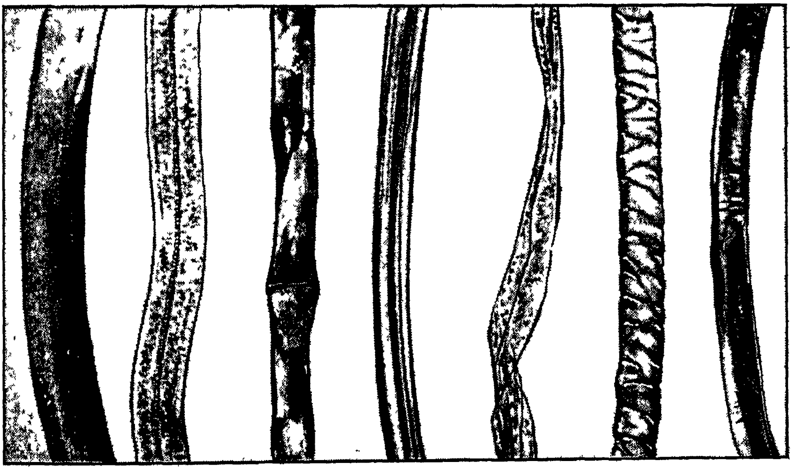
(8) Toning and colouring photographs.

17. Make a list of the ways in which photography is used in industry. Remember that there are many applications of photography in which a camera is not used and that invisible rays like ultra-violet, infra-red and X-rays may be used.

SECTION 6

The Science of Textiles

TEXTILES ARE WOVEN MATERIALS used for making clothes and furniture covers and for many other purposes in the home and in industry. All textiles are composed of units called fibres which are spun (i.e. twisted) to make thread. These threads can then be twisted together again to make yarns which are woven to make lengths of fabric. Weaving is a process rather like darning. In weaving, threads of yarn are placed along the length of a loom, as the weaving machine is called. These are the warp threads and are parallel to the selvedge of the finished fabric. The weft threads are those which are inserted across the warp in various patterns or weaves. On page 200 you will find examples of two common ones.

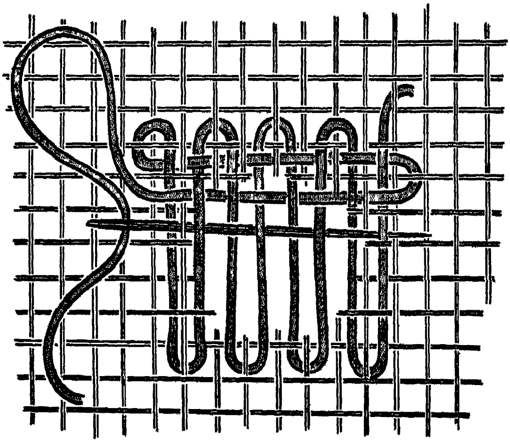


Some textile fibres as seen under the microscope.
From left to right—nylon, silk, linen, cellulose acetate, cotton, wool, viscose rayon.

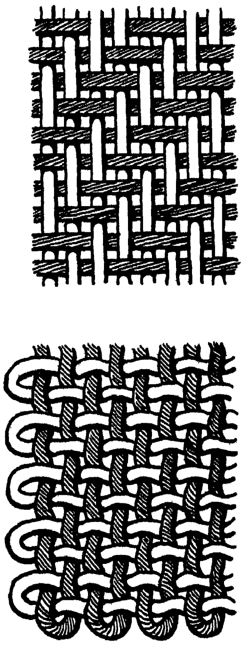
Textile fibres must be strong, flexible and elastic so that they may return to their original shape after being stretched or strained while the fabric is in use. Fabrics used for clothing should absorb moisture from the body and should also absorb water while being washed or dyed.

FIBRES SUITABLE FOR MAKING TEXTILES

The natural fibres, wool, linen, cotton and silk, have been used for making textiles for over four thousand years. In France, in 1889, the first artificial or man-made fibres, having the properties necessary for making textiles, were produced from cellulose. This is the substance,



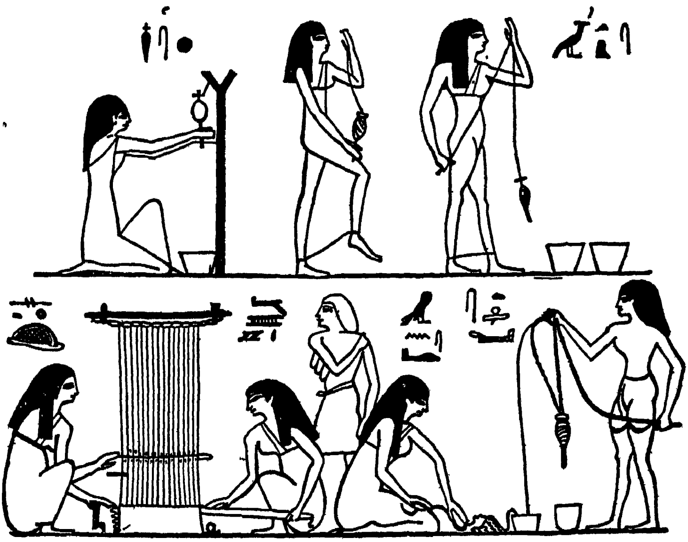
Darning



Two types of weave

similar to blotting paper, of which the cell walls of plants are made. The fabrics made from cellulose fibres were called artificial silk or rayon. The term "artificial silk" is incorrect and is no longer used. Nowadays several different

types of rayon exist and rayon fabrics are almost as popular as those made of cotton. More recently, artificial fibres such as nylon, terylene and similar compounds



Spinning and weaving in ancient Egypt. These drawings are from a pyramid

have given us new textiles and we may expect others to be produced within the next few years.

Animal Fibres

(i) *Wool.* Wool is the hairy covering of the sheep's body. It has been used for clothing for thousands of years. The name of ancient Babylonia was said to mean "the land of wool." The early rulers of Egypt were known as the Shepherd Kings. The Phoenician merchant seamen of the Mediterranean Sea who traded as far as the coasts of England, bought and sold wool. During the Roman occupation of Britain, a mill for spinning and weaving

wool was built at Winchester and became famous throughout Western Europe. It was said that this mill could spin threads as fine as any in a spider's web.

In good flocks of sheep, each animal will produce about ten pounds of wool in a year. Each hair of a sheep is one wool fibre. The hair grows in the same way as human hair (Book I, p. 28) and is sheared (i.e. cut) every year. Each fibre is covered with scales and is wavy in appearance. If you pull out some fibres from woollen materials or from knitting wool and examine them under a microscope, you will see that each consists of a row of cells. In coarse woollen fibres, a narrow canal runs down the length of each fibre. Fibres of one inch or more in length are used for making the best woollen fabrics. The wavy outline of the fibres and the scales on them help to trap air in the yarn when it is spun and in the fabric when it is woven. This trapped air is a bad conductor of heat and so woollen clothing prevents the loss of heat from the body. Wool fibres are elastic and, therefore, woollen materials do not crease easily. They are not as strong as the fibres of cotton and linen and, for that reason, must be treated more carefully in laundering. They will absorb one quarter of their own weight of moisture without becoming damp and so wool is useful for making underclothing for it absorbs perspiration without the wearer becoming chilled.

Wool yarns and fabrics burn slowly as the fibres melt. The dark liquid which is formed bubbles and crackles and gives off a smell of burning hair. A piece of damp red litmus paper held near burning wool turns blue, showing that alkaline fumes are present (Book I, p. 39): the residue is soft and black. Your teacher may show you that woollen threads are made of protein. When a few drops of concentrated nitric acid are allowed to fall on white wool, its fibres turn yellow: then, if a few drops of

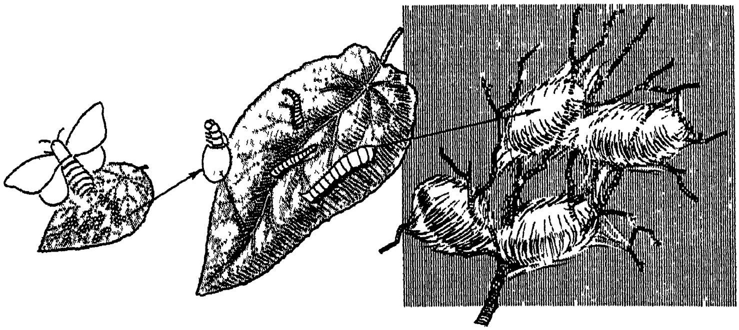
·880 ammonia solution are added, the colour becomes pink. Do not try this experiment yourself as concentrated nitric acid causes dangerous burns on the skin. Your teacher may also show you that woollen threads dissolve in a 10 per cent solution of caustic soda (made by dissolving 10 gm. of caustic soda in 90 gm. of water). If you are allowed to do this experiment yourself, remember that caustic soda is a strong alkali and can cause painful and dangerous burns. It will also char wood if any of the solution is spilled upon it. Some housewives use preparations containing caustic soda to clean their gas or electric cookers. You will understand why it is important that they should wear rubber gloves and take great care to avoid splashing other surfaces when using this dangerous chemical. Dilute acid does not harm wool.

You will now be ready to carry out the experiments with wool described on p. 224.

(ii) *Silk*. Silk fibres are made by the larvae of the silk moth. The fibre is wound round its body just before the larva turns into a chrysalis (Book I, pp. 124–6). Silkworms, as the larvae are called, are not difficult to keep in school. To obtain the silk, the chrysalids covered with the silk cocoons are plunged into hot water. This kills the insect inside and softens the gum which sticks the coils of silk together. The silk thread can then be unravelled and wound on to bobbins. There is a silkworm farm in this country, owned by Lady Hart Dyke, where films have been made, showing the whole process of the production of silk. The coronation robes of H.M. Queen Elizabeth II were made of silk produced on this farm.

The Life History of the Silk Moth. In April, eggs can be obtained from dealers. If the eggs are placed in a venti-

lated box in a warm room, they hatch and small black caterpillars emerge. The caterpillars should be placed on mulberry or lettuce leaves which they eat rapidly. If you wish to obtain good quality silk, you must provide a regular supply of mulberry leaves. If, however, you wish only to watch the life cycle of the insect and do not require silk, lettuce will do instead of mulberry leaves. You may like to feed some caterpillars on mulberry and some on



Stages in the life of the silk moth

lettuce leaves: then you will be able to record the effects of these different foods on the insects.

Like other caterpillars, the silkworm sheds its skin several times before it is full grown (i.e. when it is about three inches long). Then it is ready to pupate. The body of the caterpillar becomes much shorter and fatter than it was before and its outer skin becomes harder as the creature prepares for its resting stage (the chrysalis or pupa). A double thread of silk is produced from two small holes, called spinnerets, on the caterpillar's head and is wound round and round its body. During the next three or four weeks, the change from caterpillar to moth (metamorphosis) takes place inside the skin of the

chrysalis which is inside the silken cocoon. At the end of this time the adult moth breaks out, tearing the cocoon as it emerges. If the moths emerge in a suitable insect cage (see Book I, pp. 92–3) male and female moths will mate and the females will lay eggs on pieces of paper laid in the cage. A thread of silk more than five hundred yards long can be unwound from one cocoon. The silk from several cocoons is unwound at the same time and the threads cling together to form a thicker thread or yarn. After further treatment, strands thick enough for weaving are produced.

In some parts of the world, wild silkworms produce cocoons which are collected and used for making "spun silk." This is not as strong as the better quality silk produced by the cultivated silkworms. Tussore silk is an example of "spun silk."

Properties of silk. Silk from the cocoon feels stiff. This is because each thread is really two threads gummed together, and the gum on this "raw" silk makes it feel stiff. If you pull out a thread from a piece of silk fabric, you will see that it is one long smooth tube. The gum has been removed in the manufacturing process and the silk feels soft and looks shiny. The threads are now separate. Unlike the wool fibre, the silk fibre was not made from a row of cells but was produced by the hardening of the sticky liquid exuded from the spinnerets of the silkworm. It is finer than the wool fibre and the best quality silk fibres are very strong, about one third as strong as steel tubes of the same size. It is elastic and if stretched, will return to its original size. It will burn slowly, melting as it burns, and a small black ball remains. If you burn a small piece of silk fabric, enough fumes will be formed to turn damp red litmus paper blue. What does this test

tell you? Silk fibres are weakened by a cold caustic soda solution and dissolve in a hot solution.

Silk fabrics have the same properties as the fibres. They are soft and lustrous, strong, crease-resisting, and bad conductors of heat. They will absorb about one-tenth of their weight of water without feeling damp. Many silk fabrics produce a rustling sound when shaken.

Laundering wool and silk. Boiling water alters the chemical composition of wool and so a woollen garment which has been boiled loses some of its valuable properties. Not only caustic soda but also washing soda will damage wool. Rubbing wet woollen materials causes the fibres to slip and the material may become matted. Woollen garments should therefore be washed in warm water in which you have dissolved some good quality soap which does not contain much free alkali (Book III, p. 38, experiment 7) or some mild soapless detergent. They should be squeezed gently in the warm suds, rinsed well, then squeezed and not mangled. They should be dried in a warm but not hot place and, if necessary, ironed with a cool iron.

Fabrics made from silk should be laundered in the same way. Soda turns silk yellow. A cool iron prevents scorching.

Vegetable fibres

Cotton is more widely used for making fabrics than any other fibre. It has been used for thousands of years but no one knows where or when it was first spun. Cotton fabrics were not manufactured in England until the seventeenth century. The manufacturers of woollen and linen clothing were hostile to the new material. For a time,

it was illegal for a person to wear clothes made of cotton, and, by law, the dead had to be buried in woollen shrouds.

Cotton is made from the white fibres which cover the seeds of the cotton plant. The ripe fruit (seed case) of the cotton is known as the "boll." This splits when ripe and the white fluffy contents are picked and placed in "gins," which are large machines which separate the cotton from the seeds and bits of leaf. The cotton is then packed in bales. This is raw cotton. On reaching this country, the cotton is cleaned and prepared for spinning into yarn. The yarn may then be woven into fabrics.

Cotton "bolls"

The cotton seeds are not wasted. In ancient times the Chinese and Hindus used the oil from cotton seeds for medicine and for burning in lamps. Nowadays it is used for making margarine and salad dressing and the remains of the seeds are used for making cattle food. About one million tons of oil and three million tons of cattle food are produced every year from cotton seed. Even the short fluffy down on the cotton seed, which remains after the cotton fibres are removed, is collected and used. This down is known as "linters" and is used for making coarse cotton yarn, padding for mattresses, and for preparing pure cellulose for such purposes as making rayon fabrics and sausage skins.

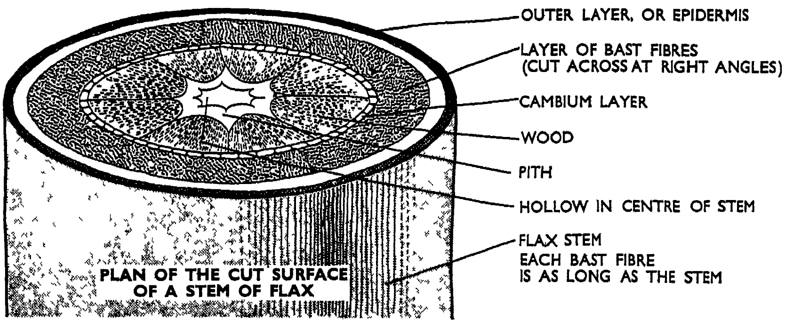
Properties of cotton fibres. Each cotton fibre consists of one narrow twisted plant cell which may be from three-quarters to one-and-a-half inches long. The protoplasm of the cell dies and only the cell wall remains. This is made of cellulose, a carbohydrate substance, which has

less elasticity than the protein fibres of wool and silk, and so cotton fabrics crease easily unless they are treated to prevent creasing. Cotton fibres absorb some moisture without becoming damp, but not as much as animal fibres or linen. Cotton is a poor conductor of heat. Fibres pulled from cotton material burn rapidly with a large flame when touched with a lighted match. Test the fumes with blue litmus paper. How do they differ from animal fibres? What colour is the ash which remains? Many accidents occur every day in the home because cotton material is so inflammable. Some cotton fabrics, however, are fire-proofed to lessen the risk of burning.

Alkalis, including washing soda, do not affect cotton, but even dilute acid destroys it if the acid is allowed to dry on the material. Cotton fibres are stronger wet than dry, and therefore cotton fabrics may be rubbed, scrubbed and mangled. Below a temperature of 150° C. they are not damaged by heat, and may be boiled and ironed. They can be ironed with a fairly hot iron. If acid bleaches are used to remove stains from cotton, the material must be rinsed thoroughly to remove all traces of acid before the fabric is dried.

Linen. Linen fibres are obtained from the bast in the stem of the flax plant. When the plant is alive, the bast carries food made by the leaves to other parts of the plant where food cannot be made. (Why are some parts of a plant unable to make food?) If you look at a transverse section of a stem of a young plant under the microscope, you may see a ring of veins. The part of each vein nearest to the centre of the stem is wood, and you learned about the wood of the Oak tree in Book I. In addition to the wood, each vein has a cap of bast. You may see this on the outer side of each vein.

Linen fabrics have been used for thousands of years. The flax plant grows best where the climate is damp and cool. The stems are crushed and bacteria help in the process of "retting" or separating the bast fibres from the



Drawing of section of flax stem

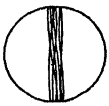
rest of the stem. The fibres are spun into yarn which may be woven into linen fabric.

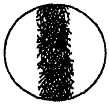
The linen fibres may be as long as the flax stem in which they were formed. Long fibres are desirable, so the flax stems are grown to about four feet high. The fibres are therefore much longer than those of wool or cotton and each is composed of a row of dead cells with cellulose walls. Under the microscope the wall has a smooth appearance, and the fibre looks rather like a bamboo pole. Linen fibres are the strongest of the natural fibres and are 20 per cent stronger when wet than when dry, and so linen fabrics wear longer than those made of cotton. They have a pleasant silky sheen. They are, however, more expensive. Linen absorbs about one-tenth of its weight of water, and water evaporates quickly from it, hence its use for washing-up cloths and handkerchiefs. As linen and cotton are both composed of cellulose, you

will not be surprised to find that linen has similar properties to cotton and can be laundered in the same way.

Man-made Fibres

The first fibre to be made by man was produced by adding nitric acid to cellulose and dissolving the product in acetic acid. The material so made was then passed through small holes, like the spinnerets of the silk worm. Under the microscope, rayon fibres look like glistening rods with longitudinal markings which were formed as the fibres shrank during manufacture.


Continuous filament yarn

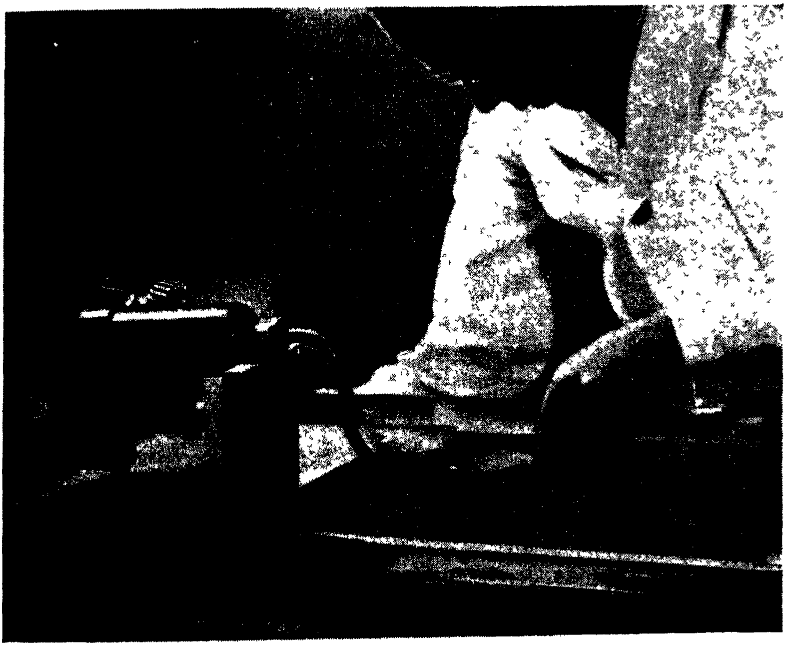

Spun yarn

Nowadays, all fabrics prepared from cellulose are known as rayons. The most important are cellulose acetate (made from waste cotton) and viscose rayon (made from wood pulp).

A sticky "spinning solution" made from cellulose is forced through many fine holes in a nozzle called the spinneret. As the threads emerge they harden, and are collected together to make "continuous filament" yarn, or they may be cut into suitable lengths or "staples" to be spun together into a "spun" yarn as natural fibres are spun. Look at the drawing of "spun" yarn. How do you think fabrics made from it will differ from those made from "continuous filament" yarn? Can you suggest uses for each of these? Cellulose acetate rayon absorbs less and viscous rayon more water than cotton. Both differ from cotton in that they become less strong when wet. Both are damaged by heat and cellulose acetate may melt at the touch of a hot iron. They are both spoiled by acids and swell up in alkalis such as caustic soda. Viscose rayon fibres are not elastic and crease easily but cellulose acetate

rayon has a silky appearance and is more crease-resistant than either viscose rayon or cotton.

In 1930, American scientists discovered how to make textile fibres from benzene. They were experimenting to find out how to make large molecules in which little groups



Man copies the silkworm (*Courtaulds*)

of atoms would be arranged in a row like the links in a chain. They knew that natural textile fibres and rubber latex have molecules arranged in this way. These long chain molecules are known as polymers. One day a new chemical was produced. In the raw state it looks like white marble chips but when it is melted down it can be pulled into threads as one can pull out hot liquid toffee. It was

named nylon polymer. The threads can be twisted together to make yarn and can be woven into a fabric which is hard-wearing, flexible and which dries quickly after washing and needs little ironing. The new fabric was called nylon.

In the making of all artificial fibres, man has copied the silkworm. The tubes through which the molten polymer is forced are called spinnerets. The threads harden as they cool and are then stretched to about four times their length. After this treatment the threads are very strong and elastic and are not easily damaged by rubbing. The threads are twice as strong as threads of aluminium of the same diameter.

The thickness of a nylon thread is shown by a *denier* number. This number indicates the weight in grammes of 9,000 metres of a thread. As the threads are long cylinders, their weight is proportionate to their thickness or diameter. Fine threads have low denier numbers: 12 and 15 denier thread is used for making fine stockings, while 210 denier yarn, made by twisting many finer threads together, is used for making very heavy ropes. The yarns naturally become stronger as the thickness increases.

Nylon fibres are almost as strong when wet as when they are dry. They do not absorb moisture easily. So, after washing nylon garments, water may be removed by rubbing them in a towel. Nylon does not shrink, and dries very quickly. As the fibres are made from mineral material and not from protein or carbohydrate, they are not eaten by the larvae of clothes moths nor by other clothes pests.

Examine some nylon fibres under the microscope. Notice the cylindrical shape and smooth surface from which the dirt is easily washed. Note how the fibres melt when touched with a lighted match. Can you detect a smell of celery? Test the fumes with wet red and blue

litmus papers. Melted nylon hardens to a pale brown bead. Nylon itself is not inflammable but may become so during certain finishing processes. A scrap of any material from which children's party frocks are to be made should be tested with a lighted match before the garments are begun.

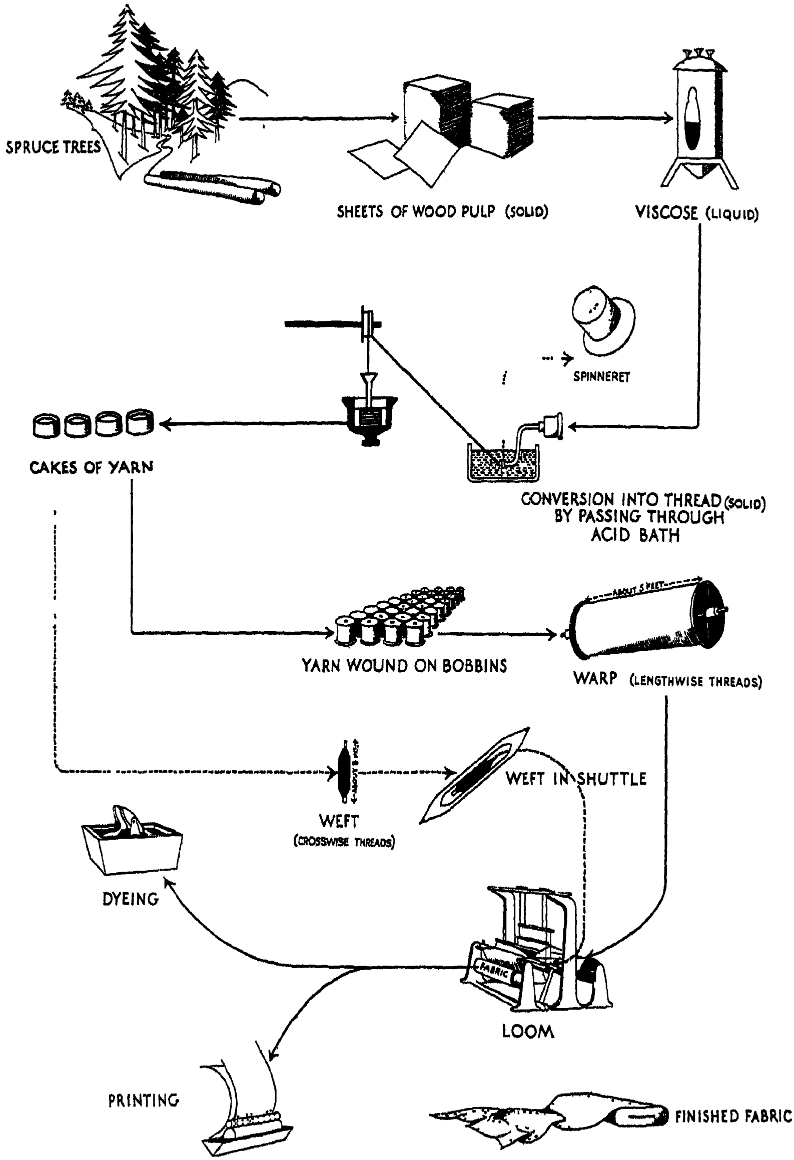
The melting-point for most nylon fabrics is 480° F. There is a lower temperature at which permanent pleats can be pressed into the material. This explains why it is that you may unintentionally iron creases into a nylon fabric if your iron is not very cool. Nylon, in fact, needs little or no ironing.

Nylon is now used for climbers' safety ropes, for fire hoses, for airmen's parachutes, for fishing nets, for ships' hawsers and for many other purposes where great strength and durability are needed. Very few chemicals harm nylon fabrics, but light gradually changes white nylon to a creamy colour.

The next artificial fibre to be invented was terylene, a British product, first made by Imperial Chemical Industries from two liquids obtained from petroleum. It has similar properties to nylon but holds even less moisture and dries more quickly.

Nylon and terylene are only two of an increasing number of fibres made from mineral substances. Some are made from glass to produce fire-proof fabrics and others from metals for the decoration of other fabrics.

More and more fibres are being made from vegetable products. For example, seaweed produces a fibre which is used for making lace. Soya beans and groundnuts produce Ardil, a protein fibre which is sometimes mixed with wool, to cheapen the product, and with cotton, to make it feel warmer and more crease-resistant. A fibre produced from skimmed milk may be added to wool fibres to produce cheaper and warmer fabrics. The search



Flow sheet showing production of viscose rayon fabric (*Courtaulds*)

for new and improved textile fibres goes on in laboratories throughout the world.

The use of Shirlastain A for help in identifying textile fibres. After you have carried out some of the other tests described in this section of the book, you may like to see whether you confirm your results when you use Shirlastain A. The results are not as reliable as those from the burning test because this test can be carried out successfully only on white material. Shirlastain A is a mixture of dyes. When different textiles are soaked in it, each kind of fibre absorbs a different dye from the stain and so cotton, for example, will be stained purple while nylon will be stained a dull yellow. Terylene is stained a very pale purple, wool becomes golden yellow, silk brownish orange, while viscose rayon turns pink, and cellulose acetate rayon turns greenish yellow. You will find instructions for carrying out the experiment on p. 227.

DYEING

From very early times, people have used liquids obtained from plants and animals for dyeing their clothing and household fabrics. A red dye, used in the time of Moses, was obtained from an insect rather like that from which we now obtain the pink dye, cochineal. You may see some of the blue indigo dye (obtained from the indigo plant) which was used in Ancient Egypt, in museums in this country. After four thousand years the indigo dye on materials brought from the Pyramids has not faded. The togas worn by Roman Emperors were dyed with Tyrian Purple, a precious dye obtained from a shellfish. You will remember that Lydia, of whom you read in the Acts of the Apostles, was a seller of purple, a dye which

came from another shellfish. In this country in the reign of Elizabeth I, brightly-coloured clothes were worn by both men and women, yet only a few dyes were known to the Englishman. Indigo and lichens for blue dyes, turmeric for yellow, madder and cochineal for pink, together with the juices of other stems, roots and berries, were used to dye woollen and linen material. Probably Drake and other explorers brought dyewoods home from their travels. Nowadays, in addition to these vegetable and animal dyes, about two thousand chemical dyes are used in Britain. Unlike the earlier dyes, some of the chemical dyes do not fade either when the fabric is washed or when it is exposed to bright sunlight.

Dyes are coloured substances which are soluble in water and which will attach themselves to textile fibres. The discovery of chemical dyes was due to William Perkin, a lad of 18, who worked as a laboratory assistant. He was allowed to work on in the laboratory in his spare time as he was trying to make quinine from chemicals obtained from coal tar. (Quinine, which has been so important in treating the disease of malaria, is obtained from the bark of the Cinchona tree.) Perkin did not succeed in making quinine, but while purifying a tarry substance, he produced, in 1856, a mineral chemical which dyed silk a deep mauve colour. Later, Nicholson prepared the first blue acid dyes for wool.

By 1885, German chemists were producing more new dyes than were British chemists, but within fifty years British chemists were again leading the world in the production of dyes for textiles. Imperial Chemical Industries have been largely responsible for later research on dyes. You may be able to see a very beautiful film (in colour) showing how one of I.C.I.'s latest dyes, Monastral Blue, was discovered This film will show you

not only the way in which research chemists carry out their work, but also what conditions are like in some large chemical laboratories. The film is called *The Discovery of a New Pigment*.

You may like to experiment on dyeing both with vegetable dyes and with the more usual home dyes. You will find suggestions for the former on p. 228. For home dyeing, material which has been thoroughly soaked in water should be lowered into the boiling dye solution made up according to instructions on the packet. Cotton materials should be boiled for another half hour, stirring constantly. Sometimes salt is added to help the dye to combine with the textile fibres.

Mordant dyeing. Many dyes will wash out of materials unless a chemical known as a mordant is also used. The mordant enables the dye to become firmly fixed to the textile fibres.

Removing stains from fabrics

As weeds in a garden are unwanted plants, so stains on fabrics are unwanted dyes. It is useful to know how to remove stains from fabrics without damaging the material. If a fabric is not harmed by water, many stains can be removed by soaking at once in cold water. If, however, a stain is allowed to penetrate the fibres of the material it may be more difficult to remove.

Some stains may be removed by dissolving in a suitable solvent. For example, a sugar or syrup stain can be sponged out with warm water. Some substances, however, such as fats, will not dissolve in water but are soluble in carbon tetrachloride or benzene. (*N.B.* Benzene, like petrol, catches fire easily and must not be used near a

flame.) A grass stain (that is, one due to chlorophyll) will dissolve in methylated spirit. A blood stain will not dissolve in a salt solution but the salt will soften it so that the stain may be removed easily when the fabric is squeezed or rubbed in water.

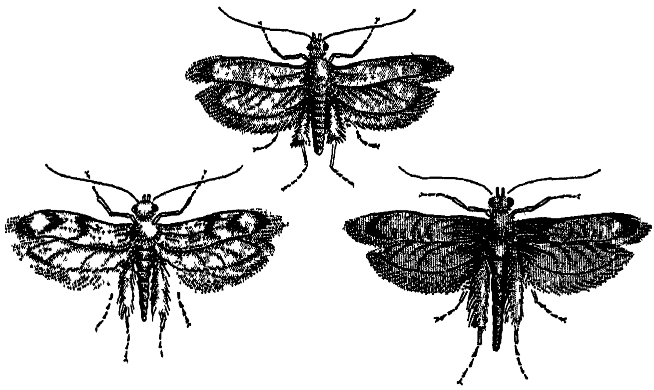
Some stains may be removed by bleaching. In bleaching, a chemical change occurs between the stain and the bleaching agent. As a result, the coloured stain is changed to a colourless substance. Bleaching agents containing chlorine are suitable for use on white cotton fabrics. Hydrogen peroxide may be used safely to bleach stains on silk, wool or rayon. Not all stains can be removed by any one bleaching agent. Carry out the experiments on pp. 225–6. Make a list of the stains and the names of the substances which you find may safely be used to remove them. Keep the list for future reference.

TEXTILE PESTS

There are a number of pests which eat the carbohydrates and proteins of which natural textile fibres are made. "Moth-eaten" is a word heartily feared by the good housewife. She dreads any signs of "moth" as much as those of woodworm. When moths are seen flying in the home on a summer or autumn evening, they are killed lest they damage clothing, carpets and upholstery. The fear is justified, but the Common House Moth does not eat textiles. The harm is done by its larvae, small white caterpillars which feed on these things.

There are four kinds of Clothes Moth and two of House Moth which are found in the British Isles. All are very destructive but the larvae of the House Moths are more harmful to carpets and curtains than are those of the Clothes Moths. All these moths are very small, having

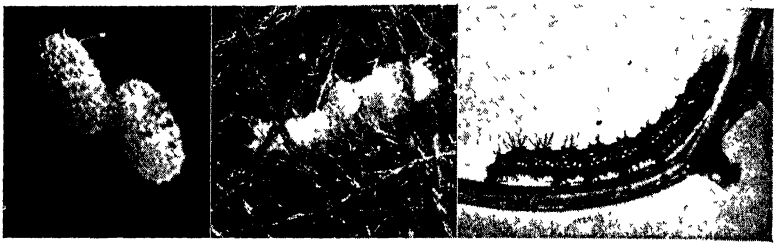
a wing span of less than one inch. When disturbed, they usually run very quickly to hide in some dark hole. The small moths seen flying are generally males. When resting, the wings of the Clothes Moths are held close to the body and sloping like a roof but those of the House Moths are held flat over the body like scissor blades which do not quite meet at the tips. The eggs are ivory yellow and about $\frac{1}{24}$ in. long. They are attached to the surface of



Some household moths

fabrics or between strands of woven wool. Each female moth lays from fifty to ninety eggs. The larvae hatch in from eight to ten days and then may eat steadily for up to three hundred days during which time they can do enormous damage. They are white but are camouflaged by the colour of the food material which is seen through their skin. While feeding they spin silken tubes in which fibres of the food material are mixed. These sometimes form a silken veil on a garment, hiding the destruction beneath. During their development the larvae shed their

skins many times and these may be seen in the seams of clothing and in the recesses of furniture. The larvae sometimes rest in a cocoon for months before beginning to feed again and to continue their life of destruction. When fully grown a larva is about $\frac{3}{8}$ in. long. It is then ready to pupate and spins for itself a dense cocoon which resembles its surroundings and is about $\frac{1}{3}$ in. long.



Eggs and larva of clothes moth. The central picture shows the larva inside a silken veil

(*Photos Mustograph, Paul Pepper, L. W Newman*)

Fur coats and textile garments may be completely protected from damage by cold storage. If that is not convenient, they may be given good protection by sunning, brushing and beating at least once a fortnight. For lack of sun, a hot fire may be used. If clothes have to be stored unworn for a long time, they should be thoroughly cleaned (for the moths prefer soiled material) and stored in polythene or other moth-proof bags, or in boxes with tight-fitting lids. Chemicals which give off moth-killing fumes, such as Paradichlorbenzene or Naphthaline should be placed in such bags or boxes (1 lb. to 6 cu. ft. of storage space). The fumes of these two chemicals are harmless to human beings and chemical sprays made from them may be freely used. Carpets and curtains which are regularly and thoroughly cleaned with a vacuum cleaner are not likely to suffer damage.

Fibre	*Countries producing largest quantities*	*Location of industry in the British Isles*
Wool	S. Africa, New Zealand, Australia	Yorkshire
Silk	India, Asia Minor, France, Italy	
Cotton	Egypt, India, America	Lancashire
Linen	Russia, Belgium, Ireland	N. Ireland

SOME SOURCES OF INFORMATION ON TEXTILE SCIENCE

You will be able to find a great deal of information about the sources and production of textile fibres, from encyclopaedias and from *Textile Science*, Parts 1 and 2, by Kemp and Oman, which can be bought from "Science Club," 82, Park Street, London, W.1.

V. Thurstan's *The Use of Vegetable Dyes for Beginners* gives practical instructions on dyeing. (Dryad Press.)

The following is a list of textile firms and other organizations which supply booklets, maps, charts and samples. If you are making a special study of one or more textiles and need the latest information, you may like to write for details. Some booklets are free and others can be purchased quite cheaply.

British Celanese Ltd. Educational Publicity Dept., Celanese House, Hanover Sq., London, W.1.

British Man-made Fibres Federation, Bridgewater House, 58, Whitworth Street, Manchester, 1.

British Nylon Spinners Ltd., Public Relations Department, 25, Upper Brook Street, London, W.1.

Cotton Board, Industry Relations Department, 3, Alberton Street, Manchester, 3.

Council of Industrial Design, Information Division, 28, Haymarket, London, S.W.1.

Courtaulds Ltd., Public Relations Department, Ivy House, 30–32, Newgate Street, London, E.C.1.

International Wool Secretariat, Dorland House, 18–20, Regent Street, London, S.W.1.

Irish Linen Guild, Public Relations Department, 8 Serle Street, Lincoln's Inn, London, W.C.2.

Sewing Silks Ltd., Perivale Mills, Greenford, Middlesex.

Silk Centre, 49, Park Lane, London, W 1.

Wool (and Allied) Textile Employers' Council, 55, Well Street, Bradford, 1.

SOME FILMS AND FILM STRIPS TO HELP YOU WITH YOUR STUDY OF TEXTILE SCIENCE

The National Committee for Visual Aids in Education issues a leaflet entitled "Films and Filmstrips for Textiles." The address is 33, Queen Anne St , London, W.1.

The following 16 mm. films are available to schools on free loan:

From the Silk Centre: the films *Silk from Mulberry* and *Queen Silk* deal with the rearing of silkworms and the production of silk.

From the Cotton Board: the films *Any Questions on Cotton?* and *Spun, Woven and Finished.* Both are sound films and are in colour.

From Imperial Chemical Industries Film Library, Bolton House, Curzon Street, London, W 1: the films *Colour* and *The Discovery of a New Pigment.* Both of these are sound films and are in colour.

TEN QUESTIONS ON TEXTILE SCIENCE

1. What do you know about weaving?

2. Say what you know about each of the following textile fibres: wool, silk, linen, rayon, cotton.

3. Why is wool a bad conductor of heat? How do we make use of this property?

4. Describe the life history of the silk moth.

5. What are the properties of a silk fabric?

6. Give instructions for laundering woollen materials and state your reasons.

7. What is rayon? How is it made?

8. Say what you know about nylon and terylene.

9. How would you use your knowledge of science to remove an unknown stain from a cotton handkerchief?

10. What is a dye? What do you know about the discovery of chemical dyes?

THINGS TO FIND OUT AND THINGS TO DO

1. Find out all you can about the history of the woollen industry in this country.

2. In what ways did these men help the woollen industry: Richard Arkwright, James Hargreaves, Samuel Crompton?

3. Draw a sketch map of the world and shade the chief areas where wool is produced. With a different colour, show the important silk, cotton and linen areas.

4. Find out from an encyclopaedia or from one of the books listed on p. 221 from which animals the following fibres come to us: mohair, cashmere, alpaca, camel hair, llama. If possible find out what each is like and for what purposes each fibre is used.

5. Some vegetable fibres used for special purposes are: kapok, hemp, jute, ramie, sisal. Find out from which plant each is produced and where each grows. What are the special uses of each fibre?

6. Collect raw wool from a hedge. Pull it into two parts. Add a little ammonia and soap to some warm water and squeeze one

piece of wool in it until it is clean. Dry it in the air. How does it differ from the unwashed wool? Wrap each piece in a filter paper. What difference do you notice in the filter papers after several days?

7. Pull out some threads from woollen materials and knitting yarns and notice the length of the fibres. Can you find any connection between the price per yard of woollen material and the length of the fibres?

8. Put a little white wool into a solution of household bleach. After ten minutes rinse and dry. What is the effect of bleach on wool?

9. Carry out the experiments with wool fibres and woollen fabrics on pp. 202–3.

10. From different pieces of materials, pull out fibres and put them on microscope slides in a little paraffin oil. Cover each slide with a glass slip and look at the threads under the microscope. Try to name the fibres from what you have learned in this book. Make named drawings of what you see.

11. Keep silkworms and carry out the experiments on pp. 204–5. Note the size of the fully-grown caterpillars and of the cocoons. Note also the colour and strength of the silk thread produced.

12. Examine a small piece of silk from a cocoon under the microscope. What do you notice? Can you explain what you see?

13. Obtain small pieces of pure silk and spun silk. Notice the differences in appearance and feel of the two materials. Pull out a thread from each and examine with a magnifying glass. Can you tell which thread is wider? Which is longer? Which seems the stronger?

14. Carry out the experiments with silk on pp. 205–6.

15. Cut some soiled cotton material into pieces about 6 in. square. Wash different pieces with cold water and soap; cold water, soap and soda; hot water and soap; hot water, soap and soda; cold water and a washing powder; hot water and the washing powder. Use different washing powders, including the new soapless detergents, on different pieces of material. Rinse and dry each piece of material and examine to see which treatment has been most successful. Is cold water or hot water better for washing cotton?

16. Find which kind of water will save the most soap. Take a rack of clean test tubes and stick a piece of gummed paper on each tube $2\frac{1}{2}$ in. from the bottom. Number the tubes. Pour cold tap water into tube 1 up to the level of the top of the paper. Put in one Lux soap flake (or any other brand of soap flake in which the flakes are all the same size and weight) and shake the tube until the flake is dissolved. Continue to add one flake at a time, shaking after each is added, until a lather remains on the water. Note how many flakes you need. Repeat the experiment in tube 2 using boiled tap water. In tube 3 use rain water or distilled water and in tube 4 some water in which you have dissolved a little washing soda. Until a lasting lather is produced, the water is destroying the soap. Which kind of water destroys most soap?

Tube	*Kind of water*	*Number of flakes needed to make a lasting lather*	*Hard or soft water?*
1	Cold tap		
2	Hot tap		
3	Rain water	1	Soft
4	Hot tap water and soda		

17. Revise the work on hard and soft water (Book II, chapters 2 and 8). Which kinds of water you have used in experiment 16 are hard and which are soft?

18. Obtain from the chemist some sodium sesquicarbonate (short needle crystals often used for making bath salts) or some Calgon. Repeat experiment 16 using cold water in which you have dissolved one of these "softeners." Make a table to show your results, and add the results of other experiments on softening water which you may think out for yourselves.

19. Pour a little household bleach containing chlorine into a beaker and dilute as directed on the bottle. Place in it small pieces of stained cotton materials which you have collected. Note which

of the following stains will be removed: writing ink, Indian ink, red ink, fruit juice, blood, coffee, tea, grass, iron mould.

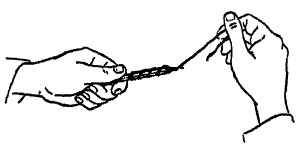
Will household bleach remove the colour from all dyed cottons or only from some dyed cottons? Carry out an experiment to find out for yourself.

Repeat the experiment using hydrogen peroxide, and try to remove stains on silk or wool.

20. Your teacher may show you that nitric acid turns wool yellow. Why does this happen? If he also drops a little nitric acid on to a piece of cotton and wool mixture fabric, notice which threads in the weave are yellow.

21. Collect small pieces of material (cotton, wool, linen, silk, etc.). Allow a drop of water to fall on each piece in turn. Which material absorbs the water most quickly? Make a list, starting with the most absorbent material and ending with the materials from which the water runs off. Now take each piece of fabric in turn, and drip water on to it from a small glass pipette or drinking straw, until the moistened part of the fabric looks wet. Count the number of drops needed to wet the fabric. Make another list to show your results. Write down what you have learned from this experiment.

22. Take a small skein of thin string. Tie one end to the blunt end of a pencil. Hold the pencil in your left hand and hold the skein in your right hand about 18 in. above your left hand. Tilt the pencil point towards your right hand and rotate the pencil between the thumb and first finger of your left hand, moving the pencil in the same direction all the time. Keep the string taut. After you have done this for about half a minute, compare the appearance of the skein in your right hand with the length of string between the pencil and your right hand. Do you notice the tightening of the string? You have carried out a simple spinning process.



Spinning

23. Visit a museum to see spinning wheels, looms and other apparatus for preparing woollen thread and for weaving cloth.

24. Collect pieces of material to test with Shirlastain A. Prepare them in the following way. First boil each piece in soap solution for half an hour and rinse well. If the fabric is coloured, try to bleach it according to instructions in experiment 19. Rinse all the bleach out of the fabric. Then soak the wet material in Shirlastain A for one minute, stirring well. Rinse with cold water and dry. Compare your results with those given on p. 215. Carry out the burning test on each of these materials and identify each. How far does the staining method confirm your results?

25. It will be difficult for you to test the strength of single fibres, but you can test the strength of threads (yarns) of wool, cotton, nylon, etc. Choose a stool with a finger-hole at the top. Tie one end of a thread round the middle of a pencil. Place the pencil across the finger-hole and pull the free end of the thread through the hole. Make a mark on the thread one foot from the bottom of the loop round the pencil. Tie the thread on to a pan which can hold weights, at this mark. Now add weights to the pan until the thread breaks. Notice the weight on the pan when this happens. Repeat with the other threads. Unravel a little of each thread to find how many thinner threads are twisted together to make it. Make a table of results showing the material, the number of thin threads twisted together, and the weight at which the thread snapped.

26. Think out experiments you could do to test whether a dye on a fabric is fast to washing and to sunlight. Carry out your experiments, write down your results, and make your conclusions. Discuss with other members of your class whether the experiment is successful.

27. Show the effect of soap and of a synthetic detergent on dirt. Obtain three clean beakers. Place in each, one level teaspoonful of black manganese dioxide. Half fill beaker 1 with cold water, half fill beaker 2 with cold water and add half an ounce of soap flakes. Half fill beaker 3 and add half an ounce of a soapless detergent. Stir the contents of each beaker briskly using a separate glass rod for each. Stop stirring and place a strip of white cotton material upright in each beaker. Examine each strip after half an

hour. Which strip is dirtiest? Which beaker contains the clearest liquid? What do you learn from this experiment?

28. Violetta Thurston's booklet *The Use of Vegetable Dyes for Beginners* (Dryad Press) gives full instructions on collecting and using many different plants for vegetable dyeing. Try to obtain this booklet and follow the instructions. You may find it among the art books in your school library.

INDEX

GEORGE ALLEN & UNWIN LTD
London 40 Museum Street, W C.1

Auckland· 24 Wyndham Street
Bombay· 15 Graham Road, Ballard Estate, Bombay 1
Calcutta· 17 Chittaranjan Avenue, Calcutta 13
Cape Town 109 Long Street
Karachi 254 Ingle Road
New Delhi: 13–14 Ajmeri Gate Extension, New Delhi 1
São Paulo: Avenida 9 de Julho 1138–Ap 51
Sydney, N S.W : Bradbury House, 55 York Street
Toronto: 91 Wellington Street West